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AGRICULTURAL RESEARCH INSTITUTE
PUSA

F. C. BRADFORD

PROCEEDINGS

OF THE

AMERICAN SOCIETY

FOR

HORTICULTURAL SCIENCE

VOLUME 40

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OFFICERS AND COMMITTEES FOR 1942

President..J. C. MILLER
Vice-President..W. P. TUFTS
Sectional Chairmen:..........R. D. ANTHONY, F. S. JAMISON, and E. C. VOLZ
Secretary-Treasurer..H. B. TUKEY

WESTERN SECTION (for 1941–42, elected June, 1941)

A. C. HILDRETH, *Chairman*
F. M. COE, *Vice-Chairman*
J. H. MACGILLIVRAY, *Secretary*

GREAT PLAINS SECTION (for 1941–42, elected August, 1941)

HAROLD MATTSON, *Chairman*
P. D. HARGRAVE, *Vice-Chairman*
M. F. BABB, *Secretary*

SOUTHERN SECTION (for 1942–43, elected February, 1942)

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B. L. WADE, *Vice-Chairman*
J. B. EDMOND, *Secretary*

EXECUTIVE COMMITTEE

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W. P. TUFTS
H. B. TUKEY
R. D. ANTHONY
F. S. JAMISON
E. C. VOLZ
A. C. HILDRETH
HAROLD MATTSON
W. S. ANDERSON
ORA SMITH (1942)
R. H. ROBERTS (1943)

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D. V. FISHER
R. B. WITHROW
S. W EDGECOMBE
C. P. HARLEY

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J. W. WELLINGTON
G. J. RALEIGH

A.A.A.S. COUNCIL

V. R. GARDNER
J. K. SHAW

BIOLOGICAL ABSTRACTS

L. G. SCHERMERHORN
H. L. CRANE

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L. R. HAWTHORN
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NOMINATING COMMITTEE

C. H. CONNORS, *Chairman*
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R. W. HODGSON
A. F. YEAGER
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K. C. BARRONS

EDITORIAL COMMITTEE

F. C. BRADFORD (1946), *Chairman*
E. V. HARDENBURG (1942)
PHILIP BRIERLEY (1943)
M. B. DAVIS (1944)
G. F. POTTER (1945)

LOCAL ARRANGEMENTS

R. B. FARNHAM, *Chairman*

NATIONAL RESEARCH COUNCIL

E. C. AUCHTER

CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS*

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve ex officio as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve ex officio as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve ex officio as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; edit, publish, and distribute the Proceedings and other publications; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve ex officio as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

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*As revised and adopted at the Philadelphia meeting, January 1, 1941,

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by this Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program, consisting of five (5) members, of which the secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Secretary in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the Proceedings.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be five dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the Proceedings of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the Proceedings.

SOCIETY AFFAIRS

RESUMÉ OF THE 1941 MEETING OF THE GREAT PLAINS SECTION

The Great Plains Section held its annual meeting in North Dakota, August 13 to 16, 1941.

Attention was given to fruit and vegetable plantings and research activities, particularly fruit breeding, at the North Dakota Agricultural Experiment Station at Fargo and at the Northern Field Station of the Division of Dryland Agriculture at Mandan. The group visited commercial nurseries and nurseries and plantings of the Soil Conservation Service and Prairie States Forestry Project in a tour which included the North Dakota Badlands.

A joint program and tour with the North Dakota State Horticultural Society on August 13 at Bismarck was concluded with a banquet at which Prof. W. H. Alderman, P. D. Hargrave, and J. D. Winter gave short talks before the 120 in attendance.

Officers elected for 1941–42 are: Chairman, Prof. Harold Mattson; Vice-Chairman, Mr. P. D. Hargrave; and Secretary, Dr. M. F. Babb.

The 1942 meeting is scheduled for the Cheyenne Horticultural Field Station, Cheyenne, Wyoming.

RESUMÉ OF THE ANNUAL MEETING AT DALLAS, TEXAS

DECEMBER 29, 30 AND 31, 1941

The thirty-eighth annual meeting of the Society was held in Fondren Library, Hyer Hall, and McFarlin Auditorium of Southern Methodist University. Society headquarters were Virginia Hall, Southern Methodist University.

There were two hundred and twelve papers listed on the program, grouped into three sections on fruits, two sections on vegetables, one on nut crops, and one on floriculture and ornamental horticulture. In addition, there were joint sessions on potato problems with the Potato Association of America, on experimental design and control and measurement of variation in physiological research with the American Society of Plant Physiologists and the Physiology Section of the Botanical Society of America, and on efficiency in recent methods for controlling field heterogeneity with the Biometrics Section of the American Statistical Association. Round tables were held on educational methods, on nomenclature and varieties, and on experimental design.

The banquet and social evening was in the hands of the Texas group of horticultural workers under the chairmanship of Dr. Guy W. Adriance of Texas A. & M. College, and featured the Southwest delightfully in entertainment, in program, and in dinner menu.

RESUMÉ OF THE 1942 MEETING OF THE SOUTHERN SECTION

The sixth annual meeting of the Southern Section was held in conjunction with the forty-third annual convention of the Association of Southern Agricultural Workers in Memphis on February 4, 5 and 6, 1942. The program carried 35 papers which were given in five sessions. Two symposia were held, namely, "Recent Research with Small Fruits" with Dr. G. M. Darrow as chairman, and "Recent Research with the Cultivated Cucurbits" with Mr. W. S. Anderson as chairman. A joint session was held with the Home Economics Section on "The Nutritional Qualities of Fruits and Vegetables". All sessions were well attended.

The banquet and social evening was held at the Hotel Claridge with Dr. H. L. Cochran as toastmaster. Visiting members from other sections were Dr. G. M. Darrow, Dr. C. A. Magoon, and Professor R. Wellington. The following officers were elected for 1942–43: Chairman, Mr. W. S. Anderson; Vice-Chairman, Dr. B. L. Wade; Secretary, Dr. J. B. Edmond. Members of the Executive Committee are Professor G. H. Blackmon (1943), Dr. W. S. Flory (1944) and Dr. H. B. Cordner (1945).

SECRETARY-TREASURER'S REPORT

Membership in the Society numbers 715 in good standing, representing a decline of 17 from last year. Loss in foreign membership has been more than made up by the increase in new members in the United States, due largely to the active work of the committee on Sectional Groups and Membership, with Dr. H. L. Cochran as chairman. There are 175 members who have failed to pay their dues, most of whom may be expected to retain their membership in the Society.

The money received from dues this year was $3,804.10, $815.85 more than last year; from the sale of Proceedings, $1,317.38, a gain of $85.13. Extra pages purchased by authors amounted to $386.20, a decrease of $234.20, and reprints and etchings amounted to $1,867.22, a decrease of $309.16.

The general condition of the Society indicates a final small gain in membership for the year, and an increase in income which balances both the extra cost of printing two volumes of the Proceedings (1253 pages) and the extra cost of increased Society activities, such as printing and circularizing programs of Sectional Meetings of the Society. It can be said that the estimates of a year ago, when dues were raised from $4.00 to $5.00 have proved accurate.

The condition of the Society is not, however, clearly pictured in the Treasurer's report if judged by the standards of former years, for the reason that outstanding accounts amount to $1,324.73, as the result of the publication of a second volume of the Proceedings late in the year, making it physically impossible to close all accounts within the calendar year. The balance on hand December 20, 1941, plus collectable unpaid bills amounts to $5,517.83, as compared with $5,603.07 in 1940. In addition, likely increases in membership revenues, as explained in the preceding paragraph, make the financial outlook and general condition of the Society appear sound.

The World War may be expected to affect the Society. The Executive Committee has already discussed various problems, such as increased cost of publication, and may be expected to act promptly upon any emergency matter that may arise.

Two additional matters appear worthy of extra effort during the year ahead, namely, first a campaign to increase membership by interesting the growing number of persons eligible for associate membership in the Society, and, second, attention to every detail that will help in the development of the regional groups within the Society as strong integral parts of the national organization.

Treasurer's Report

Receipts

Dues (1940–1941)	$3,804.10		
Proceedings sold	1,317.38		
Extra pages purchased by authors	386.20		
Reprints and cuts purchased by authors	1,867.22		
		$7,374.90	
Interest on money in savings account		64.97	
Balance on hand December 20, 1940		4,548.34	
Bills receivable, outstanding accounts (Dec. 20, 1941)		1,324.73	
			$13,312.94

Expenditures

Expenses of Philadelphia meeting	$ 99.48
Printing Proceedings, vols. 38 and 39	5,945.41
Reprints, vols. 38 and 39	837.18
Programs, envelopes, letterheads, application blanks, labels, invoices, notice of dues, etc.	253.85
Halftones and etchings for Proceedings, vols. 38 and 39	772.59
Secretary's office, including clerical assistance	425.13
Postage and express, office and shipping Proceedings	316.84
Stamped envelops	107.46

Proceedings purchased for resale	32.00		
Exchange on checks during 1941	5.17		
Total Expenditures		$8,795.11	
On hand December 20, 1941		3,193.10	
Bills receivable		1,324.73	
			$13,312.94

This is to certify that we have examined the books of the treasurer and find them well kept, easy to follow, and in general good order.

J. H. Clark
W. S. Flory, Jr.
Auditing Committee

REPORT OF THE EXECUTIVE COMMITTEE AS ADOPTED BY THE SOCIETY

The Executive Committee met at 8:15 p.m., December 28, 1941, in the Fondren Library, Southern Methodist University, Dallas, Texas. Those present were: F. C. Bradford, L. H. MacDaniels, R. A. McGinty, J. H. Clark, V. R. Boswell, J. C. Miller, H. L. Cochran, S. H. Yarnell, J. C. Ratsek, and H. B. Tukey.

All suggestions sent in by members had been mimeographed and circularized prior to the meeting so as to provide ample time for careful consideration by the committee. The committee feels that any suggestions sent in by members are of great value in shaping the policies of the Society and wishes to assure the membership that it gratefully receives any suggestions and gives them fullest consideration.

The following actions were taken:

1. It is recommended that the meeting place for 1942 be New York City in connection with the meeting of the American Association for the Advancement of Science and that the dates be fixed for Tuesday, Wednesday, and Thursday, December 29, 30, and 31, provided these dates coincide with those of societies in related fields of science as determined by consultation with those societies.
2. It is recommended, after careful consideration, that no formal summer meeting of the Society be held during 1942.
3. The following persons are proposed for election to the Nominating Committee, namely, R. W. Hodgson, A. F. Yeager, J. B. Edmond, K. C Barron, J. C. Ratsek, C. H. Connors, *Chairman*.
4. It is recommended that the present practice of printing and circularizing the programs of the regional groups, by the national society, be continued.
5. It is recommended that Article 4 of the By-Laws be changed as follows: Change "five (5)" to "four (4)". This action is advisable to make the number on the program committee conform to the provisions for its election.
6. It is recommended that when a committee member cannot be present at the annual meeting of the Society, the President of the Society be authorized to empower an alternate who may be suggested by that committee member to act for him.
7. It is recommended that unless circumstances do not permit, the Secretary of the Society be authorized to meet with the Southern, Western, or other affiliated Regional Groups of the Society at their Regional Meetings, in consecutive years.

Respectfully submitted,
L. H. MacDaniels, *Chairman*

REPORT OF THE NOMINATING COMMITTEE

In its report the Nominating Committee submitted the names of officers and committees as shown on page viii of these Proceedings, with the exception of the Nominating Committee, which was nominated by the Executive Committee in accordance with the Constitution. The secretary was instructed to cast the vote of the Society for the officers and committees as nominated, and their election was declared.

REPORT OF COMMITTEE TO ASSIST THE NATIONAL RESEARCH COUNCIL IN DEVELOPING A NATIONAL ROSTER OF SCIENTIFIC AND SPECIALIZED PERSONNEL

In the summer of 1940, at the request of the National Research Council, the president of this Society appointed a committee to collaborate with the National Resources Planning Board in the development of a National Roster of Scientific and Specialized Personnel. A brief report of that committee appears on page xvii of Volume 38 of the Proceedings of this Society. In the belief that members of the Society would be keenly interested in certain of the data compiled for horticulture and related fields, the chairman of the above-mentioned committee obtained a detailed tabulation through the courtesy of Mr. James C. O'Brien, executive officer of the project.

In the accompanying table is shown the number of persons indicating each item as their first field of specialization, and also the number indicating each as their second and third fields of specialization. Because of the manner in which these figures were compiled, neither column nor row totals will reveal the actual number of persons involved in the fields covered.

Number of persons indicating the following fields as their first, second, and third fields of specialization.

	Persons listing a field as his 1st, 2nd or 3rd field of work		
Field	1st	2nd	3rd
Fruit and nut crops			
Production	261	216	182
Physiology	68	65	72
Diseases	65	89	97
Breeding	39	41	35
Ecology	2	4	5
Group Total	435	415	391
Vegetable crops			
Production	88	99	94
Breeding	51	55	65
Diseases	42	70	81
Physiology	36	45	38
Ecology	1	2	3
Group total	218	271	281
Ornamental plants			
Production	71	70	72
Diseases	27	53	52
Physiology	17	10	16
Breeding	11	15	12
Ecology	—	2	3
Group total	126	150	155
Design of Experiments and Analysis			
Horticulture	7	14	26
Pathology	6	10	17
Group total	13	28	43
Seed production — general	6	4	9
Plant Pathology — general	7	3	–
Horticulture — general	4	5	–

Respectfully submitted,
V. R. Boswell, *Chairman*

REPORT OF THE COMMITTEE ON VARIETIES AND NOMENCLATURE

The Committee on Varieties met on December 29 for a Round Table discussion. Dr. Oberle of New York and Dr. Olmo of California presented grape variety descriptive material in line with the recommendations made last year. The group recommended that work on the descriptive blanks be continued and an effort made to get all the blanks ready for presentation at the next annual meeting. Other phases of nomenclature, variety descriptions and related subjects were discussed.

J. H. CLARK, *Chairman, pro tem*

REPORT OF THE RESOLUTIONS COMMITTEE

The Society expresses its sincere thanks:

(1) To Southern Methodist University for making available the excellent facilities of the institution for the use and convenience of the American Society for Horticultural Science; especially to Dr. E. P. Cheatum, Secretary of the Local Committee on Arrangements; Mrs. Mary B. Clark and her assistants, who supplied such excellent food and banquet arrangements; and to Mr. W. N. Babb, Business Manager of the University and his helpers, who assisted with registration and other matters.

(2) To Dr. G. W. Adriance, of the Texas group, for the fine arrangements, splendid banquet, and entertainment.

(3) To the American Association for the Advancement of Science for its helpfulness in arranging meetings and providing facilities for the discussions and demonstrations.

(4) To Dr. V. R. Boswell and the Program Committee for arranging a most enjoyable and instructive program.

LAURENZ GREENE
W. F. PICKETT
W. H. FRIEND, *Chairman*

The Phosphate Nutrition of Fruit Trees III. Comparison of Fruit Tree and Field Crop Responses on a Phosphate Deficient Soil[1]

By OMUND LILLELAND, J. G. BROWN, and JOHN P. CONRAD,
University of California, Davis, Calif.

THE Aiken clay loam as found at Paradise in the Sierra foothills is a residual soil, dark reddish brown in color and varying in depth from 6 to 40 feet. It has a heavy texture although it is very granular in structure. Phosphate deficiency in the Paradise area was first recognized some 15 years ago and has been confirmed many times in the field and laboratory. Because of its extreme deficiency this soil has become a classic and has served in many phosphate studies in several laboratories. A more complete description of this soil can be found in the soil survey (1).

Since it appeared to be the most deficient phosphate soil in California and since it was adapted to fruit trees as concerns soil depth, climate and irrigation, the Pomology Division of the University of California established an experimental orchard in this area in 1934 to test the need of fruit trees for phosphate. Eight species of fruit trees — cherry, prune, almond, peach, apple, pear, walnut, and filbert were planted. Twelve trees in each species have received phosphate in blocks of four trees each which are triplicated. These alternate with untreated plots of similar size and number. The trees are planted 20 feet apart. This paper presents some of the data obtained to date from this experimental orchard. The tree data from a single supplementary plot which is described later are not included.

A chemical study of this soil reveals that it contains about 2,000 parts per million of total phosphate. This is not a particularly low total since Marbut (2) has indicated that many of the most fertile soils in the United States do not contain more than 1,800 to 2,250 parts per million of total phosphate. Hibbard (3), using various methods proposed to measure the *available* phosphate reports a marked deficiency in all his tests. Additional studies in our laboratory at Davis using the Neubauer method showed little available phosphate and frequently the values were negative. The Cunninghamella plaque method devised by Mehlich, *et al.* (5) also gives extremely low values with this soil. This extreme deficiency of available phosphate in the Aiken soil is shown in Table I. The Yolo and Fresno soils included in this table for comparison are fertile soil types which are widely planted to orchards.

In addition to its low available phosphate the Aiken soil is characterized by a high capacity for phosphate fixation. Hibbard (4) has determined that this soil has approximately 10 times the fixing power of the average of 10 other California soils which he studied. The use of large amounts of phosphate for all crops and in the case of fruit trees, a method which places a large fraction of the phosphate in the

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[1] The authors gratefully acknowledge the assistance of J. A. Ream who planted and cared for the field plots, and of G. L. Barry who aided with the yield records.

TABLE I—COMPARISON OF THE PHOSPHATE EXTRACTED BY VARIOUS METHODS FROM THE LOW AIKEN CLAY LOAM AND THE FERTILE YOLO CLAY LOAM AND FRESNO SANDY LOAM*

Soil Series and Number	Parts Per Million in Soil as PO_4							
	Total	Neubauer	N/5 HNO_3	Truog	Lohse	N/20 H_2SO_4	N/10 HAc	1–1 H_2O
Yolo clay loam (1c)	2100	150	400	620	580	1100	730	0.20
Fresno sandy loam (30)	1600	150	1120	440	200	1250	870	5.00
Aiken clay loam (59)	2000	24	2	4	20	130	0	0.00

*Data adapted from Hibbard (2).

second and third foot of soil where many of the tree roots are found, seemed desirable because of the high fixing power. This deeper placement was accomplished by the use of a power spray rig as previously described (6). Amounts of phosphate equivalent to those applied in the deeper placement described above were applied broadcast on the surface in a single supplementary plot.

The vertical distribution of available phosphate in the fertilized and check plots has been studied both by the Neubauer and Cunninghamella tests and the latter results are listed in Table II. It appears from these data that not only has sufficient phosphate been added to be adequate for annuals but that the injection method has also increased the phosphate content in the second and third foot so that an enriched phosphate soil is also at the disposal of the deeper rooted fruit trees. Similar amounts of phosphate applied broadcast on the surface of the soil have not penetrated beyond the surface foot (see Table II). This has also been confirmed by our Neubauer data.

TABLE II—THE EFFECT OF METHOD OF PLACEMENT ON THE VERTICAL DISTRIBUTION OF AVAILABLE PHOSPHATE AS MEASURED BY THE CUNNINGHAMELLA PLAQUE TEST (AIKEN CLAY LOAM, PARADISE, CALIFORNIA)

Soil Depth (Feet)	Cunninghamella Growth (Mm)		
	Surface	Check	Injected
1	25+	4.0	25+
2	5.3	3.0	19.8
3	3.7	2.8	17.0

A measure of the extreme P deficiency in this soil may be gained from a study of the yield of potatoes obtained in 1940. When no phosphate was added the yield was 4 tons per acre and when phosphate was added alone the yield was 12 tons. Addition of nitrogen to the phosphate increased the yield to 17 tons. Nitrogen without phosphate gave little or no increase.

Response with other crops are shown in Fig. 1. These annuals were planted as inter-crops in the experimental orchard and were therefore growing in essentially the same soil and environment as the fruit trees. The fertilized plots had received two applications each of 5,000 pounds of treble superphosphate per acre, which was injected into the soil to

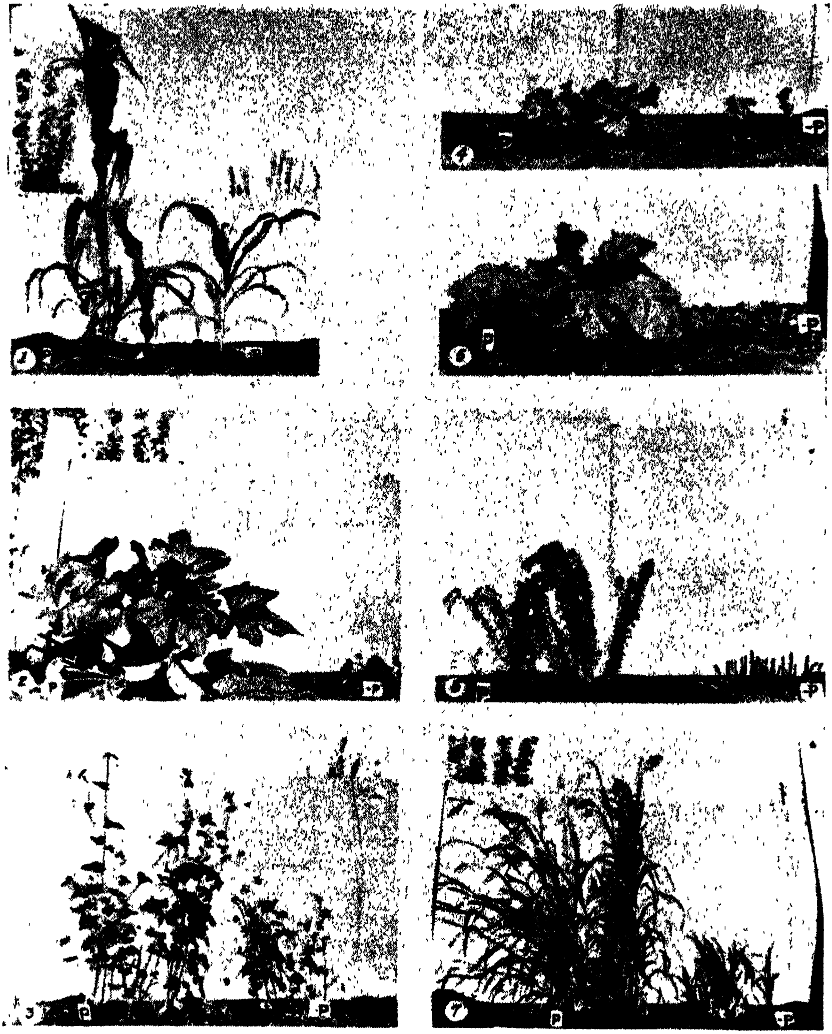

Fig. 1. Comparison of growth of intercrops on the phosphate fertilized (P) and check (–P) plots in the experimental orchard at Paradise, California (Aiken clay loam): 1, corn; 2, crookneck squash; 3, buckwheat; 4, lettuce; 5, turnip; 6, flax; 7, Proso millet. Although these and other annual crops showed a marked response to phosphate fertilization (Table III) the fruit trees in the same soil grew normally and showed no response to phosphate (Table IV).

an approximate depth of 3 feet. The first application was made in April 1935; the second in March 1936. The fertilizer treatment was designed for the deeper rooted fruit trees. The row crops were planted across the fertilized and check plots in August 1936. Adequate soil moisture was maintained by a sprinkler irrigation system.

TABLE III—YIELDS AND COMPOSITION OF ANNUAL CROPS AS AFFECTED BY PHOSPHATE FERTILIZATION (AIKEN CLAY LOAM, PARADISE, CALIFORNIA, 1936)

Crop	No. of Rows	Per Cent Dry Matter		Per Cent P in Dry Matter		Yield Dry Matter (Gms/20† Row)		Yield Factor (+P/−P)
		−P	+P	−P	+P	−P	+P	
Cucumbers	1	11.6	8.4	.15	.61	6	80	13.3
Sunflowers	2	10.7	10.8	.12	.39	305	2305	7.5
Corn	2	12.6	11.9	.16	.37	100	470	4.7
Crookneck squash	1	12.6	8.5	.25	.60	31	911	29.4
Black wax beans	2	14.7	12.2	.19	.39	240	383	1.6
Proso millet	2	22.6	24.1	.12	.47	220	1068	4.8
Lettuce	2	11.2	6.7	.14	.44	46	60	1.3*
Alfalfa	4	25.4	18.2	.16	.35	35	61	1.7
Turnip	1	11.0	8.0	.20	.54	82	545	6.6
White Federation wheat	6	24.7	16.0	.15	.36	191	499	2.6
Calcarata vetch	4	18.9	13.1	.12	.34	53	78	1.5
Hairy vetch	4	26.6	15.4	—	—	4	24	5.3
Kanota oats	4	17.6	13.6	—	—	234	568	2.4
Austrian Winter peas	2	18.6	12.0	—	—	46	93	2.0
Flax	2	20.1	18.4	—	—	21	138	6.6
Buckwheat	2	29.8	24.2	—	—	—	—	—†
Barley	4	19.3	16.3	—	—	76	498	6.6
Melilotus indica	4	30.1	17.0	—	—	11	525	4.8

*Fertilized stands were thinned; unfertilized not; −P plant averaged 0.22 grams, +P averaged 5.74. On basis of individual plants +P/−P =26.0.

†No yield data due to gopher damage. From appearance the +P was noticeably better than −P. This is clearly evident in Fig. 1.

The description, yield and composition of the intercrops planted in the experimental orchard plots are given in Table III. The crops were harvested on October 10, 1936, about the time that the pictures in Fig. 1 were taken. Greater differences in yield might have been secured with some of the crops, especially the legumes, had the harvest been delayed.

The yields per unit length of row on a green weight basis showed increases in all 18 crops from the application of phosphorus. In no case could the growth on the check plot be considered good. The legume yields were increased at least 2-fold, with Hairy vetch and Melilotus indica still higher, *i. e.*, 9-fold. Cereals made from three to eight times the yield on the phosphate treated plot while corn, sunflower and turnips increased from 5- to 10-fold. The cucurbits showed a very marked response, 18-fold for cucumbers and 43-fold for Crookneck squash. Lettuce response was also marked (Table III, footnote 1) and increased 30-fold in green weight on the phosphate treated plot.

When yields are expressed on a dry weight basis, the increases due to phosphate are also of a large magnitude. The ratios of dry matter yields between the fertilized and check plot were from 1.6 in the case of the wax bean to 29.4 in the case of the Crookneck squash (Table III). The latter appeared to be an excellent indicator plant for determining phosphate need and response. The analyses of these plants showed an enhanced phosphate content of from 200 to 400 per cent of that of the unfertilized. The latter are lower in phosphorus than is frequently reported for these crops. Leaf analyses of the fruit trees on the check plots, however, do not suggest a deficiency of phosphate (9).

Fruit trees, planted in 1934 in the same plots as these annuals, have failed to respond in growth to phosphate on a soil which appears from all present day criteria to be an extremely low phosphate soil. The growth of untreated and fertilized trees as measured by the cross-sectional areas of the trunk is given in Table IV. Not only has phosphate failed to increase fruit tree growth but it may be generally said that these trees, both the check and fertilized, compare favorably with the growth of fruit trees on more fertile orchard soils in California.

TABLE IV—GROWTH OF PHOSPHATE FERTILIZED AND UNTREATED FRUIT TREES ON A PHOSPHATE DEFICIENT SOIL (AIKEN CLAY LOAM, PARADISE, CALIFORNIA)

Species	Treatment	Trunk Cross-Section Areas (Cm)^2			
		1936	1937	1938	1939
Bing cherry	Phosphate fertilized	28	65	113	161
	Check	27	60	106	155
Agen prune	Phosphate fertilized	13	31	61	83
	Check	11	21	58	82
Nonpareil almond	Phosphate fertilized	27	71	124	186
	Check	27	74	135	205
Elberta peach	Phosphate fertilized	37	91	128	152
	Check	36	90	125	146
Franquette walnut	Phosphate fertilized	40	103	218	—
	Check	42	117	219	—
Barcelona filbert	Phosphate fertilized	14	40	103	218
	Check	14	42	117	219

In other tests on this Aiken soil, growth of nursery trees has been stimulated by heavy phosphate applications when placed in the hole at planting time (8). This appears to be associated with transplanting since no growth increase from phosphate has been observed with trees that have been established in the orchard for one or more seasons previous to fertilization even though as much as 150 pounds of treble superphosphate per tree (15,000 pounds per acre) have been added and various types of placement have been tried.

Fruit yields have not been increased by the phosphate applications. The quality and yields of fruit on both the fertilized and unfertilized plots have been very good. The Elberta peach trees produced at the rate of 11 tons per acre in their fourth leaf and continued to increase to an 18-ton production in their sixth leaf. The yield in 1941 (eighth leaf) was 16.5 tons per acre or 330 pounds per tree. The walnuts produced 25 pounds per tree in their fifth leaf and 40 pounds per tree in their sixth leaf. This is considered excellent yields for such young trees. Yields from Red Delicious apple trees in their eighth leaf were 124 pounds per tree. It has been difficult to secure exact yield data in cherries in some years due to damage from birds but the weight of fruit on the trees has been heavy enough to cause large branches on these well grown cherry trees to bend with their load. The trees produced in their sixth leaf 250 pounds of cherries per tree. Prune trees produced 60 pounds green fruit in their fourth leaf and 145 pounds in the eighth leaf. In general, there seems to be no lack of fruitfulness and no lack of fruit quality in any of the species, which can be attributed to low phosphorus.

It is of interest to note at this point some other differences between annuals and fruit trees on the Aiken soil. Edlefsen (7) of the Irrigation Division found that potatoes wilted in the field while there still was available moisture in the second foot of soil. Phosphate had been placed slightly below the seed piece at planting time. It appeared as if the dearth of phosphate in the deeper soil had limited the root development and the consequent moisture extraction below the surface foot by these potato plants. He further studied the soil moisture under our intercrops in the experimental plots and found a distinct difference between the plot which received the surface application and that which had the phosphate injected into the deeper soil. With the deeper placement of phosphate he found a deeper extraction of soil moisture. The top growth of these annual crops appeared to the eye to be about equal in the two fertilized plots. Phosphate had influenced root development as measured by soil moisture extraction.

We subsequently allowed the orchard to go unirrigated for a period and studied the soil moisture in the first, second and third foot depths under the fruit trees in the check and phosphate injected plots but could find no differences. All the samples under the trees had reached the permanent wilting point irrespective of whether the trees had received phosphate or not. This finding is not to be construed as a disagreement with Edlefsen's data but rather as a further difference between annuals and orchard trees on this low P soil.

Discussion

The differences obtained on this Aiken soil between annuals and fruit trees are similar to experiences noted by Wallace (10). Although phosphorus deficiency with fruit trees has frequently been demonstrated in sand culture (10) its occurrence in California orchards has not been established to date. The data reported by Hibbard (3) for the Goldridge sandy loam (identified as soil 78) is also of interest. This soil is distinctly low in total (450 parts per million PO_4) as well as available phosphate. Neubauer tests on this soil type from several orchards also show a low available supply. Yet apple trees on this soil in the Sebastopol area seem to grow and yield well.

It would be of interest to know whether fruit trees fail to respond because they (a) need less phosphorus than annuals, (b) can extract greater quantities from the "unavailable" source (greater feeding power), or (c) can accumulate greater quantities annually due to their perennial growth and the longer duration of root activity. Root activity of fruit trees under California conditions appears to continue throughout the winter.

Summary

The Aiken clay loam as found at Paradise, California, is extremely low in available phosphorus as determined by chemical and biological tests in the laboratory and by phosphate trials with annual crops in the field.

Eighteen different annual crops were tested and failed to make satisfactory growth unless phosphate was added.

Established fruit trees, however, showed no response to phosphate in the same soil and their growth, yield and quality of fruit were comparable with those obtained on the more fertile soils in California.

The data clearly show that phosphate responses of annual crops cannot serve as criteria of the phosphate needs of fruit trees.

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Response of Apple Trees to Potash in the Champlain Valley II. A Third-Year Growth Response and a First-Year Reduction in Leaf Scorch.

By A. B. Burrell, J. C. Cain, and L. A. Brinkerhoff,
Cornell University, Ithaca, N. Y.

EVIDENCE was presented last year (1) to show that under conditions of low soil fertility and soil management practices that supplied nitrogen but relatively little of other major nutrients or organic matter, young McIntosh apple trees responded to potassium treatments. The response consisted in a sharp reduction in amount of leaf-scorch, darker green foliage and improved fruit color limited to trees where scorch was overcome. No effect on yield was apparent, and the benefits from potassium were not evident until the second year in one experiment, and the third year in another. In September, the potassium content of leaves of trees not receiving this element was found to be exceptionally low, while the treatments had raised the leaf-content of potassium several-fold.

This second progress report presents (a) observations and results in the third year of treatment in the original plots described under Experiment I of last year; and (b) results from a new experiment with younger trees with six different potassium treatments.

Growth Response from Potassium in Third Year

This is a further report on Experiment I as discussed last year, the essential results as of that date being summarized in Table I of the former paper (1). In brief, these are McIntosh trees 11 years old, in sod, badly stunted due to poor fertility of a sandy loam soil, despite annual use of nitrogen. Four trees each received potassium for the third consecutive year in a narrow band dug into the soil. The 1940 and the 1941 applications consisted of 3 pounds of fertilizer-grade potassium sulfate (48 per cent K_2O); the 1939 treatment was the same, except that on two of the trees 1½ pounds of sulfate and 1½ pounds of muriate was used instead of 3 pounds of sulfate.

The influence of these treatments on growth and leaf-scorch is summarized in Table I, which gives comparative data for paired trees. To obtain the mean terminal growth per tree, the elongation for each of the last 4 years was measured on 15 random terminals per tree on August 28, 1941. To obtain the total terminal growth per tree in 1941, all terminals that grew 1½ inches or more were measured.

The terminal growth measurements in Table I may suggest a slight benefit from potassium previously, but in 1941, the third year of treatment, improvement in growth is clear. The 1941 growth-benefit is further illustrated by the column giving *total* terminal growth per tree. By each of these criteria the potassium-treated trees average nearly three times the growth of the untreated trees.

Table I also indicates a further reduction of leaf-scorch of the treated trees from 1940 to 1941, while the untreated trees show no consistent trend.

TABLE I—THE EFFECT OF POTASSIUM TREATMENTS ON TERMINAL GROWTH AND ON LEAF-SCORCH

Location Row Tree	Soil Treatment in Spring of 1939, 1940, 1941	Mean Growth* per Terminal (Inches)				Total** Terminal Growth per Tree (Inches) 1941	Leaf Scorch Per Cent	
		1938†	1939	1940	1941		1940	1941
71—27	None	7	10	6	5	576	62	40
71—28	K	4	6	5	10	827	5	Trace
72—27	None	9	7	4	4	644	81	60
72—26	K	5	6	6	14	2610	6	Trace
72—28	None	6	6	3	3	417	69	75
72—29	K	9	10	5	12	1748	12	Trace
73—26	None	8	10	5	2	339	75	80
73—28	L	3	6	3	7	723	22	Trace
Mean of 4	None	8	8	5	4	494	72	64
Mean of 4	K	5	7	5	11	1477	11	Trace

*Average of 15 terminals per tree.
**The sum of the lengths of all terminals making more than 1½ inches of growth in 1941.
†Before treatments were begun.

A composite sample of shoot leaves from the four untreated trees August 13, 1941 showed a potassium content of 0.70 per cent; the corresponding figure for the treated trees was 1.76 per cent. On September 20, 1940, the previous year, the untreated and the treated showed respectively 0.29 and 1.27 per cent potassium. The higher level of potassium in both groups in 1941 may have been influenced by the earlier date of sampling, and by the application of a light hay mulch around all trees in October 1940. There was some leaf-scorch on checks in 1941 at a potassium level of 0.70 per cent.

The leaf-sampling procedure was the same as last year (1). The method of analysis was similar but was performed on a smaller amount of tissue. This modification, which permitted greater speed, resulted in a slight, immaterial reduction in accuracy.

CURRENT-YEAR RESPONSE TO POTASSIUM IN NEW PLOTS

An experiment was started in 1941 on McIntosh trees mostly about 6 years of age to study the effectiveness of different potassium fertilizers and different methods of application. The trees were extremely variable, of low to medium vigor and rather small for their age, averaging about 8 inches in trunk circumference 18 inches above the ground. The soil is Coloma fine sandy loam of relatively but not extremely low fertility; the soil reaction is slightly acid. Drainage within the area varies from good to poor. The experiment was laid out according to an estimate of leaf-scorch on individual trees on September 3, 1940. There are seven treatments with either eight or nine individual-tree-units well distributed over the area for each. Only trees showing scorch in 1940 were used; the amount varied from 10 to 90 per cent, but the treatments were so assigned that the range in severity of leaf-scorch prior to treatment was similar in different lots.

The treatments and results are summarized in Table II, in which the leaf-scorch figures are an average of estimates for all individual trees getting the respective treatments. The two figures for potassium

TABLE II—CURRENT-YEAR EFFECT OF VARIOUS POTASSIUM TREATMENTS ON LEAF-SCORCH AND POTASSIUM-CONTENT OF THE FOLIAGE (1941)

Treatment*	No. of Trees	Mean Per Cent of Scorch				Per Cent K/Dry Weight Aug 13, 1941
		Before Treatment (1940)	After Treatment (1941)		Reduction Sep 3, 1940 to Aug 25, 1941	
		Sep 3	Jul 5	Aug 25		
No potassium	9	56	35	50	6	0.20 0.19
K_2SO_4 Spray: 1 per cent solution**	9	59	1	10	49	0.40 0.72
KCl Surface: 5 foot circle†	8	54	15	17	37	0.96 0.92
K_2SO_4 Surface: 5 foot circle†	8	66	17	20	46	0.92 1.27
KCl Surface: 10 foot circle	9	56	4	10	46	1.03 1.11
K_2SO_4 Dug in: 5 foot circle	8	58	11	10	48	1.07 1.07
KCl Dug in: 5 foot circle	9	53	12	20	33	0.81 0.82

*All soil applications were made May 8, 1941. The material was spread evenly over the entire area of a circle of the diameter indicated.

**Six sprays averaging 2 gallons per tree were made between May 13 (blossoms opening) and July 3; same grade K_2SO_4 as used on soil.

†KCl is muriate of potash containing 60 per cent K_2O applied at the rate of 2 pounds, 6 ounces, per tree, wherever used.

K_2SO_4 is fertilizer grade containing 48 per cent K_2O, applied at the rate of 3 pounds per tree, except in spray. Orchard is in sod, except that a circle 4 feet in diameter was hoed once a year.

All trees had a light pine-sawdust mulch applied in fall of 1940, over the hoed area, this was removed before either surface or "dug-in" application was made and partially replaced.

analysis for each treatment are for samples from different groups of trees. The first sample consisted of 25 leaves per tree from four trees; the second consisted of 25 leaves per tree from four or five other trees getting the same treatment. Therefore, the potassium-content would not be expected to check as closely as if analyses were based on duplicate samples from the same group of trees.

RESULTS

On July 5, within 2 months after application each treatment showed less than half as much scorch as the untreated check. The spray was at least equal, if not slightly more effective up to this time than any of the soil applications, only one of the nine sprayed trees showing any scorch, while among the six groups receiving soil application, from 50 to 100 per cent of the individual trees in each treatment showed at least slight scorch.

By August 25, the scorch had apparently increased somewhat more on the check trees than on the treated ones. Casual observation indicated that this was due to a longer period of growth on the treated trees. Although the *number* of leaves with scorch increased in late summer on all trees, the *percentage* was held closer to constant by the continued development of new, perfect leaves near the apex of the shoots of treated trees. It is, of course, the older leaves that show potassium-deficiency scorch first. In this experiment, no difference in effectiveness was apparent between the muriate and the sulfate of potash. Neither was there any advantage in concentrating the fertilizer beneath the branches as compared with a somewhat wider distribution. These soil applications were heavy, however, in proportion to the size of the trees, and different results might have been obtained with lighter applications or soils with higher fixing-powers.

The potassium-content of the leaves of trees not receiving potassium was exceptionally low. The spray-treatment increased it to two to three times as much, while soil application increased it to four to five times as much about 3 months after treatment. Although the soil treatments raised the leaf-content of potassium to a much higher level at mid-August than did the sprays, this is not reflected in any superiority in control of scorch. Perhaps this high level was not attained until most of the scorch had appeared; we have seen that scorch increased only slowly after July 5. The sprayed trees may have had the higher potassium content in the leaves during the spring and early summer. Furthermore, it was apparent in last year's studies that a considerable amount of scorch may persist on some branches following soil applications, even though a composite leaf-sample from the whole tree shows abundant potassium. The spray method may distribute the potassium more evenly over the entire tree. It is not impossible that additional spray applications after July 3 would have been beneficial.

It may reasonably be asked whether the spray affected the trees through leaf-absorption or only after the potassium was washed into the soil by rain and absorbed by the roots. The 12 gallons of 1 per cent K_2SO_4 solution applied during the season to each tree, contained, roughly, 1 pound of K_2SO_4, or one third as much as was applied in soil treatments. The solution was sprayed at 450 pounds pressure through a single-nozzle gun pointed nearly horizontally at the tree from several directions. Probably well over half of the solution went past the tree, much of it going 10 to 30 feet beyond. The amount therefore that would have found its way into the roots of these relatively small trees, would probably have been too little to account for the apparently prompt effectiveness of the spray treatment.

OBSERVATIONS ON ANOTHER TYPE OF LEAF-SCORCH

Incidental observations were made on a case of severe leaf-scorch of apple following Cyanamid fertilization. It should be remarked in passing that this injury resulted from placing a rather liberal amount of Cyanamid in a narrow band close to the trees shortly before tree growth started in a drouthy spring — a procedure contrary to approved practices with this material. The symptoms differed from those of the potassium-deficiency with which we have worked in that there was a more regular necrotic band with a sharply defined margin around the leaf-edge, and the brown staining, characteristic of potassium-deficiency in McIntosh, was lacking. The potassium content of a composite leaf-sample from the Cyanamid-treated row was very slightly above that of a sample from an adjoining row receiving ammonium sulfate and free from scorch (1.29 vs 1.16 per cent). Both rows had received potassium treatment. The fruits, however, on the most severely scorched branches had a type of dwarfing and dull greenish and purplish-red color similar to that described last year for fruits on branches suffering acutely from potassium-deficiency leaf-scorch. These observations support the idea that condition of the foliage is largely responsible for poor color of fruit on trees seriously deficient in potassium. On branches with less severe leaf-scorch from Cyanamid, fruits ripened prematurely but otherwise normally.

Summary and Conclusions

In an experiment starting with 9-year-old trees severely deficient in potassium, leaf-scorch was greatly reduced the second year and terminal growth increased the third year of heavy concentrated annual applications of potash dug into the soil. A striking increase in potassium-content of the foliage has accompanied these responses. Although now 11 years old, these trees still are small and have had few blossoms.

In another experiment in which rather stunted, 6-year-old trees were used, heavy applications of potassium to the soil just before bloom, greatly reduced the amount of leaf-scorch the current year. This is in marked contrast to some instances in which a lag in response to potassium has been noted (2). The results were similar whether muriate or sulfate was used, whether the material was broadcast over the entire surface of the soil within a small circle approximating the spread of the branches, over a circle of twice the diameter, or broadcast over a small circle but dug into the soil among the tree-roots. Spraying 1 per cent K_2SO_4 on the foliage gave a suggestion of more rapid control of scorch, but the possible superiority was not maintained throughout the summer. The last spray was applied July 3. About 3 months after treatment, the potassium content of leaves had been raised by soil applications to four to six times that of the exceptionally low check trees and by sprays to two to three times that of check trees.

It is not implied that acute potassium deficiency is general in the Champlain Valley or other parts of New York State, as experience indicates the contrary. Although the question is under investigation, we still have not had clear benefits from potassium treatments in the absence of the leaf-scorch symptom. This kind of leaf-scorch is very largely a young-tree trouble in the Champlain Valley.

It would be presumed that such a rapid build-up of the foliage-potassium-content would occur only with certain soils, and with trees in certain physiological conditions including very low initial potassium level. Although the spray-treatment was effective, the separate spraying of K_2SO_4 might prove costly, and there is a possibility of foliage injury from products of its reaction with arsenicals or lime-sulfur in the spray tank or with arsenicals present as residue on leaves.

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Readily Available Soil Moisture and Sizes of Fruits

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INVESTIGATORS have observed that many kinds of fruit show, by a definite change in the slope of growth curves, when the readily available moisture, or the moisture between the moisture equivalent and the permanent wilting percentage in the soil, is exhausted. There is disagreement in opinion as to the responses that may or may not be obtained when water is added to the soil before the available supply is exhausted. Some have reported significant changes in volumes of measured fruits following irrigation before the readily available moisture is exhausted. We have presented evidence in previous reports that neither Bartlett pears (1) nor Concord walnuts (3) were increased in size, nor were yields of French prunes (2) increased by applying water while readily available moisture was still present.

During the summer of 1941, experiments were conducted with 18-year-old Bartlett pear trees on *Pyrus serotina* rootstock at Davis to find out the effect of maintaining soil moisture above certain minima, on the growth and final sizes of the fruit produced. Two plots, two rows wide and seven trees long were used. Because of replanted trees 12 trees were used in the final computation in one plot, and 11 trees in the other. The trees produced light to moderate crops, and no fruit thinning was done on any of the trees. The soil in the pear orchard is classified as a Yolo loam with an average moisture equivalent of 24.3 per cent in the first 2 feet, 21.2 per cent in the second, and 21.6 per cent in the third. The respective wilting percentages were 12.5, 11.2, and 10.5. Following the winter rainfall the soil moisture was at field capacity to a depth of 6 feet or more at the beginning of the season.

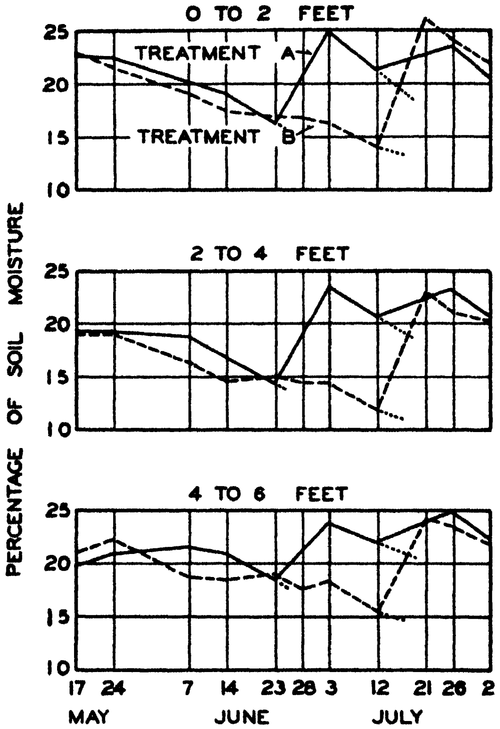

FIG. 1. Soil-moisture conditions in Bartlett pear orchard, University of California, Davis, 1941. Treatment A was irrigated on June 25 and on July 19; treatment B, on July 17.

In treatment A, an effort was made to replenish the supply while there was still ample readily available soil moisture in the top 6 feet. In treatment B, the trees were allowed to extract the moisture to a lower level, than in treatment A, before adding water. Treatment A was given two irrigations and treatment B, one. All of the irrigations moistened the soil to the moisture equivalent to a depth of 6 feet or more. The moisture contents are shown graphically in Fig. 1. In this figure it will be seen that both treatments had approximately the same soil moisture conditions until the first irrigation given to treatment A, which was on June 25. Following this irrigation, the soil moisture in treatment B was lower than in A for 22 days or until July 17 when B was irrigated. Treatment A was irrigated the second time on July 19 after which both treatments had about the same soil-moisture conditions. From the curves it will be seen that treatment A was reduced to about 16 per cent in the first 2 feet, to about 14 in the second, and to about 18 in the third on June 25, which was 2 days after the samples were taken. Similarly, when the supply was replenished on July 19 the soil-moisture content had reached about 18 per cent in the first 2 feet, 19 per cent in the second and 21 per cent in the third. At this time the moisture content of the bottom 2 feet was still high. In terms of percentage of the available supply, the first irrigation was applied to treatment A while there was about 30, 28, and 77 per cent of the available supply in the depths previously mentioned. The supply was replenished again when about 47 per cent of the available water was still present in the first 2 feet, 78 per cent in the second, and 95 per cent in the third. In treatment B, water was applied just before the readily available supply was exhausted in the top 4 feet, and while there was about 40 per cent of the available supply in the 4-to-6-foot depth.

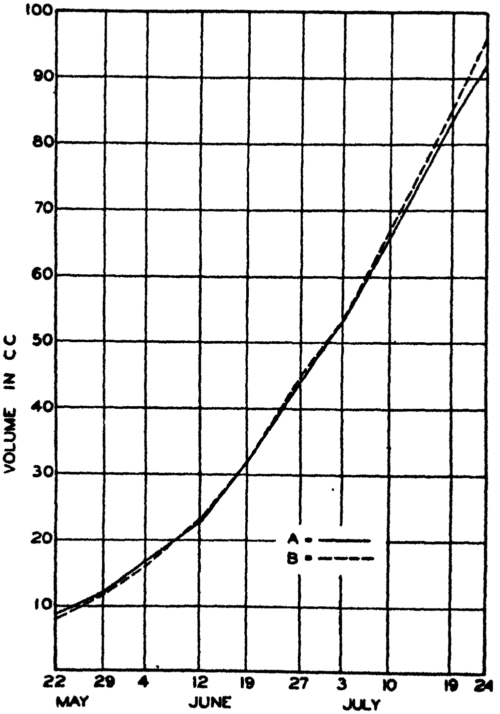

FIG. 2. Volumes of Bartlett pears, University of California, Davis, 1941.

Circumference measurements of 100 tagged fruits (25 on each of four trees) were taken in both plots at approximately weekly intervals. The results are shown in Fig. 2 in which the volumes of pears are given, assuming the pears to be spherical. The growth of the fruit was essentially the same throughout the season until the last measurement when the fruit in the high moisture plot grew slightly, but not significantly, less rapidly than that in treatment B. Perhaps some of the fruit in the high moisture plot reached maturity before those in the low moisture plot, although no differences in maturity were noticeable when the last measurements were made.

The pears were harvested in two pickings. The weight and the number of fruits were found for each tree in the experiment. The average weight per pear was .32 pounds in each treatment. The fruit was then graded and the weights and numbers of marketable fruit (2⅜ inches or more in diameter) obtained. Fig. 3 shows the relation between the total number of Bartlett pears on each tree to the weight of marketable fruit. When plotted as a straight line where X equals the numbers of fruits and Y equals the weights of marketable pears the equation $Y = 0.2595x - 7.925$ represents the results secured from the high moisture plot and $Y = 0.2605x - 4.491$ those from the low moisture plot. The plotted lines are nearly parallel and so close together that it is apparent the weights of the marketable fruits were related to the numbers of fruits on the trees and were not affected by the differences in soil moisture previously described.

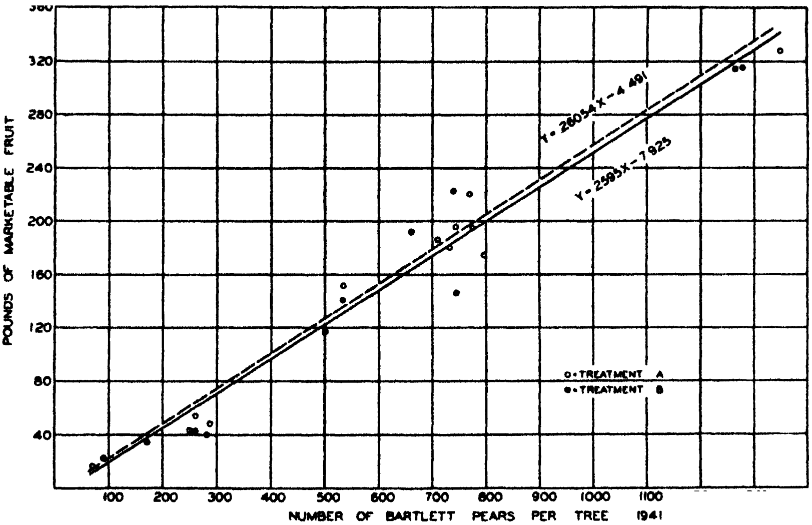

FIG. 3. Relationship between weights of marketable pears and total numbers of fruits. Y = weights of pears (2⅜ inches or more in diameter), and X numbers of fruits per tree.

Similar results were obtained from Phillips Cling peaches. Treatment A contained three plots and treatment B, four plots. The soil-moisture conditions were essentially the same during the season as those in the pear orchard. Treatment A was irrigated three times before harvest and treatment B, twice. The moisture content of the soil in treatment A in the top 6 feet did not fall below about 30 per cent of the available capacity. In treatment B, the soil moisture was reduced to a lower level than in treatment A before the supply was replenished and on one occasion reached the permanent wilting percentage in the top 3 feet. Treatment A received 21.1 acre inches of water and treatment B, 15.8 inches. The fruit grew at about the same rate in both treatments. At harvest time the weights and numbers of fruits on the individual trees were obtained. The weights of marketable fruits (2⅜ inches in diameter) were plotted against the total numbers of fruits on each treee. The weights of marketable fruits ranged from about 60 to 300 pounds, and the total numbers from 100 to 775 per tree in both treatments. The relationship between total numbers of fruits on the trees and the weights of the marketable sizes were $Y = 0.420x + 7.30$ for treatment A, and $Y = 0.422x + 12.05$ for treatment B. The curves plotted from these data are parallel and close together indicating that the weights of marketable fruit were influenced by the numbers of peaches on the trees, but not by the soil-moisture conditions.

In a third series of experiments with French prunes both treatments contained six plots. As in the peach experiment, treatment A was irrigated three times and treatment B, twice. Soil moisture in treatment A was above 25 per cent of the readily available supply most of the time in the top 3 feet but went slightly lower for a few days early in July. Treatment A received 20.5 acre inches of water and treatment B, 13.4 inches. Measured fruits in each treatment grew at approximately the same rate. The crop was harvested and dried in the usual manner. After drying, the prunes from each plot were separated into six sizes on a commercial sizer. The weights in each of the 6-size grades were plotted against the total number of prunes. The equations for the curves in which Y = the weights of prunes in the various sizes and X = the total numbers of prunes in thousands per tree, are given in Table I.

TABLE I—RELATIONSHIP BETWEEN WEIGHTS OF SIZES OF DRIED PRUNES (Y) AND NUMBERS OF FRUITS PER TREE (X)

Dried Prunes Per Pound	119	83	68
Treatment A	$Y = 4.43x - 19.24$	$Y = 3.66x - 10.97$	$Y = 2.54x + 2.06$
Treatment B	$Y = 4.30x - 17.29$	$Y = 3.65x - 13.17$	$Y = 2.48x - 0.50$
Dried Prunes Per Pound	**60**	**54**	**50**
Treatment A	$Y = 0.91x + 15.61$	$Y = -0.40x + 21.65$	$Y = -0.78x + 17.36$
Treatment B	$Y = 0.67x + 17.02$	$Y = -1.16x + 29.78$	$Y = -1.10x + 20.45$

The numbers of prunes in treatment A range from 3,350 to 17,900 per tree, and in treatment B from 4,650 to 15,000. The average weights ranged from 7 pounds per tree in the large size fruit to 35 pounds in the small size.

When plotted, the curves for the first four sizes (119, 83, 68, and 60 prunes per pound) are parallel or nearly so. The slopes of the curves gradually decrease in steepness from the first to the fourth size and show an increase in weight with the increase in total number of fruits. In the last two sizes (54 and 50 prunes per pound) the curves slope downward from left to right showing a slight decrease in weight in these two sizes with increasing numbers on the trees. With the possible exception in the fifth size, the curves are close together, showing that the weights of the various sizes were related to the numbers of prunes on the trees rather than to the soil-moisture conditions. The extra water applied to treatment A had no effect on the sizes in five out of six cases, and in one case the effect was very slight.

DISCUSSION

From the evidence presented in Fig. 3 it is clear that the marketable sizes of Bartlett pears were related to the numbers of fruits on the trees. It is also apparent that weights of marketable fruits were not influenced by the irrigation treatment, so that maintaining the soil moisture high did not produce a greater weight of marketable fruit, than allowing the soil moisture to reach a relatively low level in the readily available supply.

Further evidence that variations in soil moisture within the available supply did not affect the size of pears is shown in the growth curves (Fig. 2). These curves are essentially parallel and show no evidence that the fruits from the high moisture plots grew faster than those from the low moisture ones. Furthermore, the fruits in the low moisture plots grew as fast as the others during the warm long days of late June and the first half of July, indicating that water was as readily available in the former plot as in the latter, even under relatively severe climatic conditions. It is evident that in studying the effect of soil moisture on yields of marketable pears, the total numbers of fruits on the trees must be considered in order to avoid misleading conclusions.

The evidence presented shows that Phillips Cling peaches and French prunes behaved in the same way as the Bartlett pears. The periods of high moisture conditions, two for the pears and three each for the peaches and prunes, in treatment A, as compared with one for the pears and two each for the peaches and prunes in treatment B did not bring about a difference in the sizes of the fruit produced. Inasmuch as lack of readily available moisture is generally indicated in fruit by a retarded growth rate, and by smaller size than is the case where the trees are kept supplied at all times, the fact that differences were not obtained in rate of growth, and that trees bearing substantially equal numbers of fruits produced about the same weights of marketable fruit leads to the conclusion that moisture is readily available at all soil-moisture contents from the moisture equivalent to about the permanent wilting percentage.

The results with these three fruits show the necessity of considering the total number of fruits per tree as well as the weights of fruit of marketable sizes in interpreting experimental results.

It is interesting to note that similar results were obtained with the pear and peach trees which produced light crops and with prune trees some of which produced exceptionally heavy crops, and some very light ones.

CONCLUSIONS

Sizes of fruit and yields obtained with Bartlett pears, Phillips Cling peaches and French prunes show that soil moisture is readily available between the moisture equivalent and the permanent wilting percentage.

Weights of various sizes of pears, peaches, and prunes from trees kept supplied with readily available soil moisture were related to the total number of fruits on the trees and not to the different soil-moisture conditions.

No evidence was obtained to indicate that any benefit, as far as final sizes are concerned, could be obtained by keeping the soil-moisture content high.

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A Survey of the Relationships Between Leaf Nitrogen, Fruit Color, Leaf Color, and Per Cent of Full Crop in Some New York McIntosh Apple Orchards, 1941

By DAMON BOYNTON and J. CARLTON CAIN, *Cornell University, Ithaca, N. Y.*

A PAPER by Magness, Batjer and Regeimbal (2) has indicated the probability that percentage of nitrogen in the dry weight of apple leaves is correlated with color of fruit at harvest time. If satisfactory relationships between leaf nitrogen and fruit color, and between leaf nitrogen and average yield can be established for the McIntosh variety in New York, leaf nitrogen analyses may be useful in prediction of the effects of various combinations of soil management and fertilization practices on the balance between color and yield. This report summarizes the results of a survey made to test those general relationships under a rather wide range of soil, management, and climatic conditions during 1941.

PROCEDURE

Seventy-eight McIntosh blocks in western New York and the Hudson Valley were included in the study. The trees were under good commercial care, at least 10 years old, and were bearing at least 25 per cent of a full crop. They were reasonably exposed to light on all sides, and included 10 trees close to each other which were relatively uniform in size and appearance. The orchards were situated on important orchard soil types. A fair number of blocks showed extremes in leaf color; that is, the leaves predominantly were either extremely dark green or extremely light yellow green in midsummer. The remainder were fairly well distributed between these extremes.

In each orchard the soil management and fertilization pactices for the past few years were recorded and the soil type was determined by examination. Ten relatively uniform trees close to each other were chosen for the experimental unit. In July, 20 leaves in approximately median positions on shoots were taken from each of the 10 trees; the 20-leaf samples from five trees were composited into one sample for analysis, and the 20-leaf samples from the other five trees were composited into the duplicate sample for analysis. The composite samples were subsequently dried at 60 degrees C, ground, and analyzed for total nitrogen by the Kjeldahl method. Per cent nitrogen figures presented in Table I and Fig. 1 represent the average for the two samples from each block.

Estimates of leaf and fruit color and of yield were made as close to harvest time as possible. Usually not more than 3 days elapsed between the time of estimating and harvest. In a few instances, a week elapsed; but these were counterbalanced by cases in which the time of estimating practically coincided with harvest.

Each fruit color percentage presented in Tables I and II and Fig. 1 is the average of 200 estimates; for 20 well-exposed fruits on each of the 10 trees the percentage of the surface covered by a desirable quantity of red was recorded. Leaf color was estimated in a like manner; 10 representative median shoot leaves were taken from each tree and grouped according to four color charts from Maerz and Paul[1] (1).

The total crop and the bearing capacity of each of the 10 trees were estimated and from those estimates the average per cent of total crop figures presented in Table I were determined.

RESULTS

Fig. 1 shows graphically the relationship between per cent N in the leaves and estimated fruit color. The correlation coefficient r = —0.52 shows a high degree of statistical significance (greater than 99 to 1). The regression of color on per cent leaf N was —.31, indicating that a 1 per cent increase in leaf nitrogen might on the average be associated with a decrease of 31 per cent in fruit color, considerably less than the decrease suggested by the study of Magness, Batjer, and Regeimbal. The discrepancy between these two studies, however, may be due mostly to the different varieties, different regions and seasons, and different times of sampling leaves. Most noteworthy is the fact that the same general relationship is clearly demonstrated by both investigations.

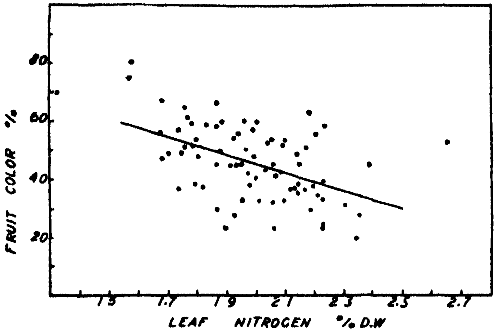

FIG. 1. Relationship between estimated average per cent of fruit surface well-colored at harvest time and per cent nitrogen in McIntosh leaves sampled in July, 1941.

There was a general positive correlation between estimated per cent-of-full-crop and leaf nitrogen (see Table I). Obviously one year's crop does not necessarily reflect the average yield of an orchard. And it is entirely possible that leaf nitrogen percentages in an orchard may fluctuate perceptibly due to size of crops alone. Nevertheless it is interesting that this relationship seemed to exist in a year when heavy spring frosts occurred during the blooming period of the McIntosh, and that this relationship seemed to exist in a group of orchards no one of which bore less than about 25 per cent of a full crop.

Tables I and II suggest the most obvious results of this survey. According to Table I, when leaf nitrogen was below 1.80 per cent,

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[1] The following charts were used as standards:
For group 1 (darkest), plate 23, C 1 to C 4;
For group 2 (moderately dark), plate 23, L 1 to L 4;
For group 3 (moderately light), plate 22, J 1 to J 4;
For group 4 (very light), plate 22, L 1 to L 4.

When possible comparisons were made in full daylight at between 7 and 8 a.m. The charts were not identical with leaf colors but were helpful in forming a stable basis for comparison.

TABLE I—PER CENT DISTRIBUTION OF McINTOSH ORCHARDS WHOSE LEAVES CONTAINED DIFFERENT NITROGEN PERCENTAGES IN JULY 1941, SORTED ACCORDING TO AVERAGE FRUIT COLOR, AVERAGE PER CENT OF FULL CROP, AND AVERAGE LEAF COLOR AT HARVEST TIME

Range of Percentage N in Dry Weight of Leaves	<1.80	1.80–1.89	1.90–1.99	200–2.09	2.10+
No. Orchards in Each Group	15	11	14	12	26
Estimated Average Fruit Color*					
Less than 50 per cent	20	45	64	67	73
More than 50 per cent	80	55	36	33	27
Estimated Average Per Cent Full Crop*					
Less than 60 per cent	67	45	36	33	31
More than 60 per cent	33	55	64	67	69
Estimated Average Leaf Color*					
1 and 2 (dark)	27	64	86	83	96
3 and 4 (light)	73	36	14	17	4

*See procedure for methods of estimation.

80 per cent of the orchards in the group produced fruit of excellent color, but only 33 per cent of those orchards had crops 60 per cent of maximum or better. In three-quarters of those orchards, leaf color was relatively light. On the other hand, when leaf nitrogen was 2.10 per cent or more, only one-quarter of the orchards in that group produced fruit of excellent average color, but two-thirds of those orchards had crops 60 per cent of maximum or better. Practically all of the orchards in the group had dark green leaves. Between those two per cent N groups, the situation with respect to fruit color, per cent of full crop, and leaf color was intermediate.

TABLE II—PER CENT DISTRIBUTION OF McINTOSH ORCHARDS SHOWING DIFFERENT ESTIMATED FRUIT COLOR, SORTED ACCORDING TO LEAF COLOR

Range in Estimated Average Per Cent Fruit Color	<40	40–49	50–59	60+
No. Orchards in Each Group	27	19	21	11
Estimated Average Leaf Color*				
1 and 2 (dark)	100	74	62	27
3 and 4 (light)	0	26	38	73

*See procedure for methods of estimation.

Table II shows the relationship between fruit color and leaf color that was expected, since both seemed to vary with per cent leaf nitrogen. But at the same time that these general relationships are brought out, this survey also shows the wide range in fruit and leaf color and per cent of full crop that may occur in orchards at any one leaf nitrogen level in one growing season. The data indicate that neither leaf nitrogen nor leaf color is an infallible criterion of fruit color or tree yield, but that they may be useful together, in indicating extreme nitrogen excess or starvation in an orchard.

There was some evidence to suggest that in 1941 when leaf nitrogen was above 2.10 per cent of dry weight, orchards on shallow soils were more apt to produce fruit of satisfactory color, than orchards on soils that permitted much deeper rooting. While orchards in which leaf nitrogen was high were usually more heavily fertilized with nitrogenous fertilizers than those which were low in leaf nitrogen, there were numerous exceptions. Cultivation, heavy pruning, and heavy mulching were associated in some orchards with high leaf nitrogen and poor color. There were also sod orchards with high leaf nitrogen which had received little or no supplementary fertilization or mulching for several years. In the orchards in which potassium supplements were used, fruit color was not consistently different from the color in orchards with the same leaf nitrogen levels to which no potassium was applied.

While this survey suggests the promise of nitrogen analysis of McIntosh leaves as a diagnostic tool, more information must be accumulated concerning the effects of soil, season, crop, and spray materials, among other factors, on leaf nitrogen, yield and color before leaf nitrogen analysis can have practical utility.

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The Influence of Porosity of Some Orchard Soils Upon Root Behavior[1]

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THE relationship between soil porosity and the movement of gas and moisture within the soil has been established by Baver (1) and others. That a similar relationship exists between moisture and aeration conditions would be expected, since under conditions of Michigan orchards, development of roots appears to be conditioned largely by these factors. The failure of roots of nut trees to penetrate certain horizons of dense subsoil has been attributed by Schuster and Stephenson (4) to deficiency of air capacity induced by prolonged conditions of high soil moisture. In dense and compact subsoils, drainage of free water is similarly impeded, and there is likewise a restricted air capacity as has been shown by Boynton and Reuther (2).

Root observations of some Montmorency cherry trees in the orchard of the Experiment Station at East Lansing have shown that certain horizons of compact subsoil were definitely unfavorable for root development. In one instance, roots were restricted, almost entirely, to one side of the trunk, and in another, all roots appeared to be concentrated in a small core immediately beneath the trunk with only a few roots penetrating the large mass of soil beneath the tree. Wherever the soil was friable, on the other hand, there was free development of roots throughout the profile. Considerable killing of roots was observed in surface horizons underlain by compact subsoils, and it seemed that the nature of the subsoil determined the extent of root killing. Later porosity studies, however, showed only a small volume of non-capillary pore space in surface horizons in which killing occurred, thus permitting rapid penetration of frost. Wherever the surface soil was loose and friable, the amount of root killing was negligible. A sudden drop in temperature to —11 degrees in January 1940, at a time when the soil was free from snow was responsible for the injury.

From observations in the orchard, it was impossible to determine definitely whether physical impenetrability, deficient aeration, or some other factor was responsible for the root restriction in compact subsoils. By studying the root growth of some indicator plant in undisturbed cores of soil of varying compactness and structure in the greenhouse, it was possible to determine the suitability of soils for root development to much better advantage than could be done in the orchard. The introduction of aeration treatments to artificial soil-sand cores made this determination more complete. Alfalfa was selected as the indicator plant for greenhouse studies, primarily on account of its high oxygen requirements, in which it may resemble many of our tree fruits, according to Gourley and Howlett (3) and others. Alfalfa has the further advantage for such studies that it is adaptable to short day and greenhouse conditions.

Since any disturbance of the natural field structure makes radical changes in the physical characteristics of a soil, the cores were removed without altering the structure. These were approximately cylindrical in shape and 8 to 10 inches in diameter. Cans of approximately 5-gallon capacity were prepared with about 2 inches of coarse sand in the bottom for drainage. Sand was tamped lightly into the space around the cores, and about 1 inch of sand was added to the surface. Moisture control was effected by maintaining the sand continuously moist, and since opportunity for free drainage was provided, the soil cores were held under conditions of uniform tension.[2]

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[1] Journal Article No. 573 (n.s.) from the Michigan Agricultural Experiment Station.

Cores were taken in duplicate from different profiles representing both favorable and unfavorable structure and compactness. One-year old alfalfa plants were dug from the field in October, and five plants selected at random were set in each can in the sand surrounding the cores. It is noteworthy that an alternative rooting medium was provided, that is, plants might produce roots in the sand and within the soil cores, or they might produce all their roots in the surrounding sand.

Artificial soil-sand cores were constructed in duplicate using finely ground soil from compact horizons, and quartz sand. By varying the proportion of soil to sand, and puddling these constituents as uniformly as possible, it was anticipated that cores could be constructed with varying amounts of non-capillary pore space. From examination and porosity studies, it was shown that little variation in porosity occurred between different soil-sand mixtures. Cores of the following mixtures were constructed in duplicate: ½ soil–½ sand; 5/12 soil–7/12 sand; ⅓ soil–⅔ sand; and ¼ soil–¾ sand.

A system of forced aeration was effected in a series of six cans containing artificial soil-sand cores of uniform composition by running an air tube through the base of the cans into the soil cores, and movement of air was created by means of a gentle suction. The volumes of air removed were 300, 600, and 900 milliliters daily, the rate of removal being constant in all treatments.

RESULTS

Examination of the cores showed that roots penetrating into them followed the well-developed cleavage planes, root and worm holes, and other natural passages within the soil. In the most compact subsoil studied, there was little penetration of roots except along the cleavage planes themselves. Nodules were found and there was considerable lateral branching in natural passages in some of the most compact cores, indicating that aeration conditions there were more satisfactory than within the compact soil clods. Nodulation and lateral branching occurred to a larger extent in soils of high non-capillary pore space.

In undisturbed cores from the A horizon in which considerable root killing occurred, there was little penetration of roots into any part of the cores, excepting where a few old root channels were found. No planes of cleavage were observed, and the structure resembled that of the puddled artificial soil-sand cores. Porosity studies showed only a small volume of non-capillary pore space.

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[2] Moisture determinations of artificial cores showed approximately 1 per cent variation between duplicate cores.

FIG. 1. Cross section of unaerated soil-sand core.

The almost complete failure of root penetration into all unaerated artificial cores is significant (Fig. 1). There was a matting of roots on the periphery of the cores, but few roots penetrated more than 1

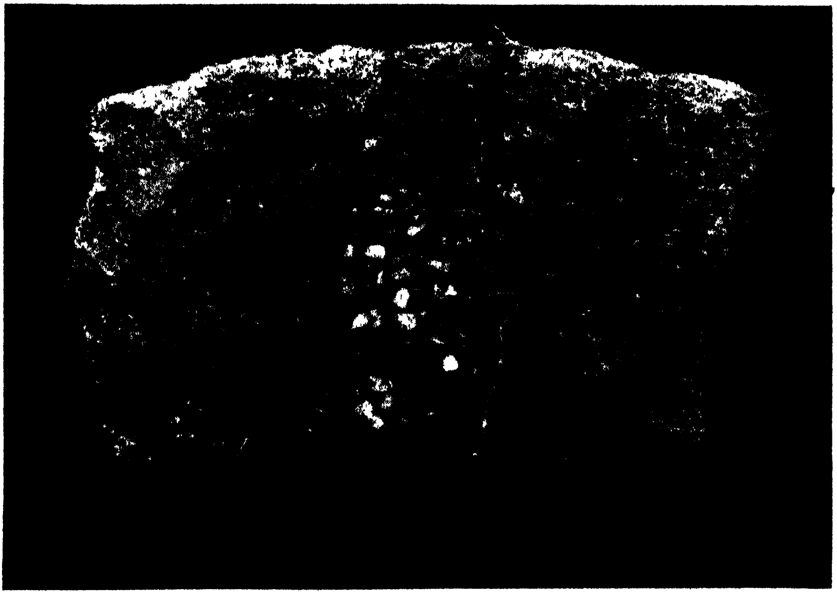

FIG. 2. Cross section of aerated soil-sand core.

inch from the surface, regardless of the proportion of soil to sand. In those cores receiving aeration, however, (Fig. 2) even for the shortest daily period, there was a profuse ramification of roots through all parts of the cores. It would have been informative to have applied similar aeration treatments to undisturbed cores from the A horizon.

CONCLUSIONS

The fundamental importance of aeration for root growth of alfalfa in artificial soil-sand mixtures, and in undisturbed soil cores under greenhouse conditions has been demonstrated. It is assumed that similar results would have been obtained by using fruit trees or other plants of similar aeration requirements.

The application of these conclusions regarding the relationship between soil structure, aeration and root development of fruit trees under orchard conditions was not established.

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The Rate of Respiration of Apple Roots

By DAVID G. WHITE and N. F. CHILDERS, *Ohio Agricultural Experiment Station, Wooster, Ohio*

ABSTRACT

This paper will be published in full in *Plant Physiology*.

SINGLE shoots of one-year Stayman Winesap trees grafted on French Crab were grown in 5-gallon glazed crocks by the gravel culture method. The Ohio WP nutrient solution was used (3). Experiments were performed when the shoots were 3 to 5 feet high and had been in leaf for approximately 10 months.

Grafting wax was used to seal the top of the crocks. Temperature about the roots was continually recorded by a soil thermograph. Respiration of roots within the crock was determined once every 24 hours as per cent increase in carbon dioxide and decrease in oxygen. The Haldane-Graham (2) type of gas analysis apparatus was used. The culture solution was maintained near pH 5 to inhibit carbon dioxide absorption by the solution. The respiration of microorganisms in the culture medium in one experiment was determined after removing the tree. This measurement permitted correction for the true respiration of the roots. The development of microorganisms in other experiments was inhibited by the addition of 5 parts per million of copper sulfate to the nutrient solution.

At the end of an experiment the volume and the fresh and dry weights of both fibrous and of the total root system were determined. It apparently made little, if any, difference as to which root measurement, volume or weight, was used to express the rate of root respiration. However, milligrams per gram of dry fibrous roots permitted the use of more convenient figures.

The typical range of root respiration was 6 to 10 milligrams of carbon dioxide released and oxygen used per gram of dry fibrous roots per 24-hour period at 63 to 68 degrees F. Fresh air was supplied the roots each day. Respiration was not measurably affected when the roots were submerged in the culture solution for a 24-hour period. However, continued submergence for a 4-day period was followed by a doubling in the rate of root respiration when fresh air was added the fifth day. Thereafter, the rate decreased to almost the initial rate.

Re-utilization of the same culture air about the roots was accompanied by a fairly constant level of root respiration until the air contained 5 to 6 per cent carbon dioxide and 8 to 9 per cent oxygen. The rate of root respiration decreased markedly thereafter until fresh air was added, whereupon the rate increased to almost double the initial rates. On the following days the rate of root respiration decreased to near the initial rates.

From these experiments and data obtained by Boynton (1) and his co-workers it seems probable that in most orchard soils the natural soil aeration, certainly at the lower depths, would not be sufficient to enable roots to carry on maximum rates of respiration.

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Aggregation of an Orchard Soil Under Sod, Mulch, and Cultivation

By A. Leon Havis, *Ohio Agricultural Experiment Station, Wooster, Ohio*

Abstract

This material will be published in full in an Ohio Agricultural Experiment Station Bulletin.

AN ANALYSIS was made of the water stable soil aggregates in the A and B horizons of Wooster silt loam soil which had been under sod, mulch, and cultivation treatments for long periods of time. The treatments in orchard C had been in progress for 26 years, and the sod and mulch treatments in orchard A had been continuous for the previous 42 years. The aggregate analysis was made by the Yoder (wet screen) method on air dry soil. Seven size classes of aggregates were made varying from a class of those over 2 millimeters in diameter to a class composed of those below .05 millimeters.

The aggregate sizes obtained by this method were strikingly different under the sod, mulch, and cultivation treatments. The mulch showed the greatest amount of aggregates among the larger sizes; sod resulted in almost as much aggregation, whereas the cultivated soil contained only small aggregates. Even in the A horizon there were few soil aggregates over 1.0 millimeter in diameter under the cultivation, whereas there was approximately 24 per cent of the dry weight of the soil under mulch and 18 per cent under sod in orchard C composed of aggregates over 1.0 millimeter in diameter. The same general trend of differences was indicated in orchard A. The B horizons in both orchards showed the same trends in results, but the differences between treatments were not so striking.

Aggregation results from sod, mulch, and cultivation treatments which had been in progress 2 to 6 years showed little differences in aggregate size distribution. This indicates that only under relatively long time treatments is obtained the advantage of the larger aggregates under the mulch and sod soil treatments under the cultivations of these studies. The number and stability of the aggregates in the larger sizes was increased more quickly under the mulch than under bluegrass sod, and is not in direct relationship to organic matter content.

Fruit Maturity and Growth of Apple Trees as Affected by Boron Content (Preliminary Report)

By L. P. Batjer and M. H. Haller, *U. S. Horticultural Station, Beltsville, Md.*

SOIL applications of borax were made to Jonathan, Delicious, Rome Beauty, Grimes Golden, and York Imperial apple trees growing in soils relatively low in available boron, for the purpose of studying boron content of the tissues as related to tree performance. No definite symptoms of boron deficiency had been observed in any of these varieties in the orchard used. Applications were made in 1940, 3 weeks prior to bloom and were at the rate of ⅓ pound of borax to 8-year-old trees and 1 pound to 20-year-old trees.

No visible effect on the trees resulted from the applications, nor was there any measurable effect on growth after two seasons. Very little varietal difference in boron content of leaves or fruit was obtained. In September 1940 the boron content of leaves from terminal shoots on the treated trees averaged 45 parts per million, as compared with 30 parts per million for the check trees. The fruits showed a much greater rate of accumulation, having an average of 50 parts per million from the boron trees, as compared with 13 parts per million from the check trees.

Pressure test measurements on the fruits of the various varieties at harvest in 1940 indicated no appreciable difference in firmness due to the boron treatment. However, the fruits from trees receiving borax softened slightly faster in storage. Jonathan fruits from the borax plots removed from storage January 1 and post-ripened for 1 week at 70 degrees F had 50 per cent spoilage from breakdown and decay, whereas check fruits had only 20 per cent. York Imperial showed no difference due to treatment, while other varieties behaved similarly to Jonathan but to a less marked degree. Delicious from experimental plots receiving borax, harvested a week to 10 days in advance of the normal harvest period, developed an average of 6 per cent storage scald as compared to 38 per cent for the checks. There was very little decay or breakdown in either check or treated fruits. When fruits were harvested at about the normal harvest period for the variety, the check lots developed somewhat more storage scald, but this condition was offset by a greater amount of decay and breakdown in the lots of fruits receiving boron.

In 1941 preharvest drop was much greater on the borax-fertilized trees. Prior to the normal harvest period Jonathan trees receiving boron had an average accumulated drop of 33 per cent as compared to 10 per cent for the checks. Grimes Golden had 23 and 6 per cent and Delicious 45 and 12 per cent for the treated and check trees respectively.

Fruits on boron-fertilized trees generally developed color earlier than that not receiving boron. In the case of Jonathan this difference was particularly striking, with fruit on borax-treated trees averaging 65 per cent color on August 28, 1941, as compared with 37 per cent for the checks.

Earlier color and dropping, coupled with a greater amount of breakdown and less scald during storage with fruits from the borax plots would indicate that the borax treatment had advanced fruit maturity. It is hoped that fruits harvested and stored in 1941 at intervals considerably in advance of the normal harvest period will give additional information on maturity relationships. The specific effect of boron on fruit maturity is also being investigated.

Preparing Soil Profile Mounts: Method and Demonstration

By Matthew Drosdoff, *U. S. Department of Agriculture, Gainesville, Fla.*

A METHOD of preparing soil profile mounts is proposed which consists simply of applying a film of clear lacquer to a rectangular piece of pasteboard and sprinkling on it an excess of dry soil. This is an old, simple and inexpensive technique which has not always been successful because the glue or other sticky substances used have not been satisfactory. In the proposed technique a clear lacquer is used which is almost transparent when dry and holds the soil firmly. A number of glues and lacquers were tried but the most satisfactory was the clear lacquer supplied with Plicote aluminum laboratory paint.

The details of the procedure are as follows: A rectangular piece of smooth double-faced corrugated board is cut from any large pasteboard box. A convenient size is 7 inches wide and about 24 inches long. The depth of the horizons and the type of boundaries are marked off on the cardboard on a scale of 4 inches to the foot. Thus, the 24-inch mount would represent a soil profile 6 feet in depth, and a 6-inch surface soil would be 2 inches in depth on the mount. The lacquer is brushed on the cardboard in a uniform film. Most of this first application soaks into the cardboard within a few minutes and a second application is immediately made which usually remains long enough for the soil to be put on. The soil samples representing the different horizons are then sprinkled on beginning with the surface horizon and following with each horizon in succession down the profile. The soil that is used is usually put through a 20-mesh screen although concretions, stones, lumps of soil and so on, have been successfully glued to the cardboard in the manner outlined. An excess of each soil horizon is sprinkled on so that none of the lacquer shows after the soil is applied. The mount is allowed to remain in place overnight. It is then lifted up and tipped sideways and the excess soil allowed to fall off leaving the remainder firmly stuck to the cardboard. The mount may then be fitted into a suitable frame made of ½ inch quarter-round nailed to a plyboard back. A scale is marked off on a thin strip of white drawing paper the length of the mount, and is attached to the side of the mount.

Influence of Boron Application on Preharvest Drop of McIntosh Apples

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THERE is a marked variation from year to year with respect to the preharvest drop of McIntosh apples among orchards in a given locality and in individual trees in the same orchard. Relatively high temperature just before harvest and various conditions of weather or soil which bring about a high nitrogen content of the tissue in relation to the supply of carbohydrates seem to increase the severity of the drop (2, 3, 4).

The following experiment indicates that an excessive preharvest drop of fruit may also be associated with incipient stages of boron deficiency which may not be severe enough to cause cork or drouth spot.

MATERIALS AND TREATMENTS

The experiment was carried out in the Cornell University orchard at Ithaca, New York, on a 20-year-old block of 90 vigorous McIntosh trees originally propagated on dwarf root stocks. The soil on which these trees were planted varies from a deep sandy loam in the southeast corner of the block to a heavy clay soil in the north and northwest portions. The entire block has received unusually heavy nitrogen fertilization during the past 10 years and is covered by a luxurious stand of quack grass (*Agropyron repens* L.) which has remained undisturbed for the past 8 years. The crops borne by the trees have been satisfactory, but since 1934 the preharvest drop has been much heavier than in other parts of the orchard with a moderate application of nitrogen.

In 1936 it was first observed that some of the windfalls showed a slight browning of the flesh around the core, but there was no evidence of external cork (1). Again in 1939 the windfalls showed browning of the flesh with a considerable variation among individual trees. No external symptoms of boron deficiency, however, were observed in that year, a season in which cork was prevalent in many orchards in New York and New England. However, in the spring of 1940 soon after the fruits began to develop, it was apparent that some of the small apples showed obvious symptoms of boron deficiency. Out of the total of 90 trees there were 8, on the sandy knoll on the southeast corner of the orchard which showed some fruits with surface cork. These trees were grouped according to the degree of injury and along with one pair of trees showing no symptoms, they were set aside for subsequent study.

On July 18th, 1940, one tree in each group received ½ pound of borax applied in about 3 gallons of water and distributed evenly in a rim 2 to 3 feet inside the drip of the branches. Determinations of boron in the soil and in the tissue of the leaves and fruit were made at several periods, using the method of Naftel (5). Samples of soil and leaves from other sections of the Cornell orchard and from the Champlain Valley were also analyzed to learn something about the range of boron.

RESULTS

In spite of the severe outbreak of cork on certain trees during 1940, there was no external evidence of the deficiency disease during the growing season of 1941 on either the checks or the treated trees. Soon after the first of September 1941, however, it became apparent that the trees receiving boron applications during the previous year obviously lost fewer fruits than the untreated trees. Nevertheless, none of the windfalls showed browning of the flesh such as occurred in 1936 and again in 1939. The preharvest drop and the total drop through harvest is recorded in Table I.

TABLE I—PREHARVEST DROP OF McINTOSH APPLES WITH AND WITHOUT BORON APPLICATIONS

Lot No.	External Cork in 1940	Tree No.	Borax Applied July 1940	Preharvest Drop to Sep 11, 1940 (No. Fruits)	Drop Through Harvest Sep 29, 1941* (Per Cent of Total Yield)
1	Severe	A1	None	254	56
	Severe	A2	None	497	70
	Severe	A3	½ pound	62	43
2	Severe	B1	None	649	87
	Severe	B2	None	596	75
	Severe	B3	½ pound	99	36
3	Trace	C2	None	629	91
	Trace	C4	½ pound	110	51
4	None	E2	None	80	32
	None	E3	½ pound	108	44

*About 10 days after commercial harvest. Total yield per tree average 13.5 bushels, trees planted 20 by 20 feet.

The data suggest that the borax applications on trees susceptible to cork reduced the preharvest drop as well as the drop through harvest as compared to the trees not receiving treatment. The moderate application of boron to the tree previously free from cork had no definite influence.

Results of the analysis of the leaf tissue, presented in Table II,

TABLE II—BORON IN LEAVES FROM McINTOSH APPLES†

Tree No.	Jul 3, 1940	Aug 15, 1940 (Ppm in Dry Matter)	Sep 15, 194
A1	10.3	11.4	9.7
A3	7.9	9.4*	5.8*
B2	5.2	6.1	10.0
B3	4.5	7.0*	8.3*
C2	4.7	8.5	9.1
C4	9.2	13.9*	14.3*
E2	8.3	12.7	9.7
E3	8.6	20.3*	14.4*
Average 4 normal trees	—	18.5	—

*Trees treated with ½ pound borax July 1940.

†Each sample consisted of the 4th and 5th leaves below the terminal bud of 50 vigorous shoots. Boron determined by method of Naftel (5) using a photoelectric colorimeter.

indicate that the boron content in all cases was relatively low before treatments in early July 1940, even in the leaves from trees showing no deficiency symptoms. There was a definite increase within a period of 6 weeks, especially on the trees which bore few or no apples with surface cork. Other analysis indicates that the boron content of the leaf tissue of normal trees tends to increase as the season advances.

Analysis of the leaf tissue made in the fall of 1941 showed a slightly lower boron content than the previous year in several cases even where boron had been applied. It should be noted, however, that the borax treatment reduced the drop even though there was not always an accompanying increase in the boron content of the leaf tissue.

In this connection it is of interest to note that the average boron content of the leaf tissue from untreated trees in the Champlain Valley orchards in which cork is much more prevalent than at Ithaca, was 12.8 parts per million of dry matter. In that region the applications of boron increased the content of this element to 38.0 parts per million of dry matter, much more than was found after a single application at Ithaca.

The boron content of the surface 10 inches of soil on the experimental block at Ithaca varied from 2.8 to 4.0 with an average of 3.4 gamma in 100 grams of air dried samples. The sandy portions of the orchard on which the trees showed the greatest tendency to produce corky apples had a slightly higher boron content than the portions with heavier soil on which no cork was produced. Comparable samples from another plot of soil from the Cornell orchard planted to McIntosh trees showed an average of 4.4 gamma of boron under quack sod, and 6.5 under heavy mulch. Soil from orchards in the Champlain Valley in which boron deficiency symptoms on untreated trees are common (1) showed 11.8 gamma per 100 grams of air dry soil when no boron had been applied. Evidently the analysis for boron by the methods used does not furnish an entirely satisfactory indication of probable response of trees. Factors influencing availability such as difference in pH of different soils are undoubtedly involved.

In 1940 determinations of boron on apparently healthy fruits from limbs of four trees having at least 5 per cent of the apples with cork showed an average of 2.48 parts per million in the dry matter. Similar fruits from limbs on the same trees on which none of the fruits showed deficiency symptoms had an average boron content of 5.43 parts per million. The boron content of fruits from trees entirely free from cork was 4.62 parts per million. Unfortunately, no analyses were made of fruits borne in 1941. It appears that the boron in the dry matter of young fruits is less than in leaves.

It should be emphasized that the results presented in this paper were obtained under conditions where the boron content of the soil and of the foliage was at a relatively low level. It is known that the limits of tolerance for boron are narrow, and injury to the leaves may result from too heavy applications of this element (1). It is probable that on bearing trees the fruit may be injured and induced to separate from the tree by excessive application even before the leaves show chlorosis in response to toxic concentrations just as they apparently are among the first tissues to respond to incipient stages of boron deficiency.

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Some Results in Controlling the Pre-Harvest Drop of Apples

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AN INCREASING interest is being shown in the growth-substance sprays which have proved effective in delaying the pre-harvest drop of apples. The use of these materials was quite general throughout the fruit districts of New York State during the 1941 harvest. Several orchard tests were again conducted to make observations on the practice and to study various factors influencing the results (3).

A comparison between a dust and a liquid spray,[1] both of which contained naphthalene acetic acid as the active ingredient, was made in a small block of Williams Early Red. The materials were applied between 6 and 7 p.m. July 29. Conditions were ideal for dusting. There was no wind and a temperature of 72 degrees F prevailed. The results are given in Table I.

TABLE I—Effect of Naphthalene Acetic Acid Spray and Dust on the Dropping of Williams Early Red (Materials Applied July 29 — Fruit Picked August 9)

Treatment	Per Cent Drop*
Check	82.2
0.001 per cent naphthalene acetic acid spray	2.2
Naphthalene acetic acid dust	1.5

*Average four trees per treatment, 10-years-old, 7.2 bushels total yield per tree. Temperature at time of application 72 degrees F.

In this test the dust was just as effective in preventing the drop of Williams Early Red as was the liquid spray. These preliminary results created considerable interest in the possibility of dusting as a method of applying the hormone. Trees can be dusted much faster than they can be sprayed. For this reason a dust may, in some cases, have a decided advantage over a liquid spray.

A similar but more extensive test was made in a vigorous 16-year-old McIntosh orchard in the lower Hudson Valley area. The materials were applied on September 1 when it was observed that sound, commercial apples had started to drop from some trees. The second spray for those trees receiving the duplicate application was made on September 5. Maximum temperatures above 80 degrees F were recorded on both days. The results are given in Table II.

The identical trees were used for a drop-control experiment in 1940; but, the results that season were negative because the checks dropped only 1.5 per cent of their crop during the 10-day period prior to harvest (2). With different weather conditions in 1941, mainly higher temperatures throughout September, the checks dropped exactly one-fourth of their crop between September 1 and harvest on September 11. Each of the naphthalene acetic acid treatments resulted in less than

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[1] The American Cyanamide and Chemical Corporation through its representative, Dr. J. L. Horsfall, furnished a grant for collecting field data and supplied from its laboratories all dusts and other chemicals used in these tests.

TABLE II—Effect of Naphthalene Acetic Acid Spray and Dust on the Dropping of McIntosh (First Spray and Dust September 1; Second Spray September 5; Fruit Picked September 10, 11, 12)

Treatment	Cumulative Per Cent Drop—Original Crop*									
	Days After Spraying									
	2	3	4	5	6	7	8	9	10	11
Check	2.0	5.7	7.4	9.9	12.9	14.9	19.2	22.9	25.2	—
Naphthalene acetic acid dust	0.9	2.4	2.7	2.9	3.6	3.8	4.5	6.4	—	—
0.001 per cent naphthalene acetic acid spray	1.3	2.8	3.2	3.6	5.0	5.1	6.1	7.8	—	—
0.001 per cent naphthalene acetic acid spray, duplicated	1.5	3.2	3.5	3.9	4.7	4.8	5.0	5.3	5.8	5.9

*Average 10 trees per treatment, 16-years-old, 16 bushels total yield per tree. Maximum temperature September 1, 92 degrees F; September 5, 84 degrees F.

8 per cent drop during this pre-harvest period. The dust was fully as effective in drop control as was the liquid spray. There is some indication that the duplicate spray added to the effectiveness of the initial application. At least, the trees receiving two sprays dropped only 5.9 per cent of the crop over an 11-day period, while those sprayed once dropped 7.8 per cent over a 9-day period.

The pre-harvest drop of McIntosh in Western New York during 1941 seemed more variable than in the Hudson Valley area. This was probably associated with the drier growing season in Western New York which would have favored a condition of excessive carbohydrates as related to the nitrogen content of the tissues. In one Western New York experiment where six 18-year-old McIntosh trees averaging 30 bushels per tree were used in each treatment, the pre-harvest drop of individual check trees varied from 6 to 18 per cent during the 15-day period between treatment and harvest. The average drop for all treatments was as follows: check, 11.9 per cent; single application of liquid, 5.5 per cent; duplicate application of liquid, 3.0 per cent; single application of dust, 5.2 per cent; duplicate application of dust, 2.9 per cent. The cumulative per cent drop from day to day clearly showed that the initial applications of liquid and dust were made about 4 days too early. Had these treatments been delayed to coincide more closely with the beginning of drop, a single application of either material would probably have given as good results as the duplicate treatments.

Working with Baldwin in Rhode Island, Murphy (4) reported that the hormone sprays were of no apparent value in preventing fruit abscission. Judging from the dates given in connection with Murphy's experiment, it seems likely that the Baldwin in question had reached picking maturity without appreciable drop about the time the spray was applied. The harvest was made 16 days later. It is possible that the hormone becomes less effective as picking maturity or a condition of over-maturity is reached.

When such late varieties as Baldwin and Spy are grown in northern latitudes, cool weather will, in many seasons, prevent an excessive drop until the fruit has reached or passed prime picking condition. Furthermore, the hormone spray seems to be much less effective at low temperatures than at high temperatures. Because of these facts, the desirability in using the spray on late varieties in northern latitudes will depend considerably on seasonal conditions.

During 1941, warm weather prevailed throughout the apple harvest season in New York State. Baldwin started to drop severely in some orchards before satisfactory color and maturity were reached. Eight trees were included in each of the treatments reported in Table III.

TABLE III—EFFECT OF NAPHTHALENE ACETIC ACID SPRAY AND DUST ON THE DROPPING OF BALDWIN (SPRAYED AND DUSTED OCTOBER 1; FRUIT PICKED OCTOBER 11)

Treatment	Accumulative Per Cent Drop—Original Crop*								
	Days After Spraying								
	2	3	4	5	6	7	8	9	10
Check	2.5	5.6	8.4	11.9	20.2	28.7	34.1	45.7	55.6
Naphthalene acetic acid dust	1.7	3.4	4.7	5.5	7.4	9.5	11.8	13.7	17.8
0.001 per cent naphthalene acetic acid spray	2.8	4.9	6.3	7.0	8.8	11.4	13.6	15.4	18.9

*Average 8 trees per treatment, 30-years-old, 23 bushels total yield per tree. Maximum temperature October 1, 76 degrees F.

The materials were applied on October 1 when the temperature ranged between 70 and 76 degrees F. All trees in the test were picked October 11.

These apples had started to drop at the time it was decided to make the test. In fact, 1 to 2 bushels of commercial grade fruit had fallen from each tree on October 1 when the materials were applied. If the treatments had been given several days earlier, it is possible that a better control of drop would have been obtained. Under the conditions of this test the hormone dust was just as effective in controlling the drop of Baldwin as was the liquid spray.

Table IV shows that under similar weather conditions the harvest spray might be profitably used on Northern Spy. The grower picked the check trees first because of the rapidly increasing drop of good fruit. The greatest loss of fruit from the checks occurred during a moderately strong wind which started the night of October 9 and lasted through the morning of October 11. The wind was not violent enough to break spurs or pull stems from the fruit. Practically all of the drop apples

TABLE IV—EFFECT OF NAPHTHALENE ACETIC ACID SPRAY ON THE DROPPING OF SPY (SPRAYED OCTOBER 4; FRUIT PICKED OCTOBER 11 AND 14)

Treatment	Cumulative Per Cent Drop—Original Crop*						
	Days After Spraying						
	3	4	5	6	7	8	9
Check	2.3	4.5	7.3	14.5	16.3	—	—
0.001 per cent naphthalene acetic acid spray	0.1	0.2	0.3	0.6	0.7	1.4	1.4

*Average 7 trees per treatment, 30-years-old, 18.8 bushels total yield per tree. Maximum temperature October 4, 80 degrees F.

had separated from the spur at the abscission zone indicating that the process of abscission was well under way on check trees but had been delayed by the spray on the treated trees.

Discussion

Following the dusting of the Williams Early Red trees (Table I) on July 29, rain started during the night and continued throughout the forenoon of the next day. With the exception of a light shower about noon on September 4, three days after the McIntosh (Table II) were dusted, there was no rain during the periods covered by any of the other tests. However, light to moderately heavy dews occurred each night. Some moisture may have been necessary for the control of drop secured with the dust.

Talc was the carrier used to make the naphthalene acetic acid dust. The concentration of naphthalene acetic acid in the talc was such that 1 pound of the dust was equivalent to approximately 10 gallons of .001 per cent spray. The physical properties of this dust allowed it to flow very freely. The machine used in the Williams Early Red and McIntosh tests was not equipped to regulate the flow. As a result, much dust was wasted and the dusted trees were credited with receiving about three times as much naphthalene acetic acid as the sprayed trees. A different duster was available for the Baldwin test and it was possible with this variety to apply more nearly equivalent quantities of naphthalene acetic acid by the two methods. The sprayed trees received 30 gallons of liquid, while 3½ pounds of dust was used in the case of each dusted tree.

Gardner, Marth, and Batjer (1) reported that increasing the concentration of the growth substance within certain limits, 1 to 5 parts per million, inrceased the effectiveness of drop control. These investigators also called attention to the probability of a natural ceiling of effectiveness beyond which greater concentrations would not be desirable. In some of the tests with dust reported here, it is quite likely that much more naphthalene acetic acid was applied than was necessary for the results obtained. This work was entirely exploratory. The results, however, would seem to justify a more complete study of dusting as a means of applying growth substance chemicals for drop control.

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Further Studies on the Control of Preharvest Drop of McIntosh[1]

By LAWRENCE SOUTHWICK, *Massachusetts Agricultural Experiment Station, Amherst, Mass.*

DELAYED abscission of apples following the application of growth-substance sprays has been reported by several investigators. In practically all cases, the active substance or substances have been dissolved in water and the mixture applied as a spray. The possibility of using a dust as the carrier has not received so much attention. The present report gives some comparative results of dust and spray applications and gives further data on certain other phases of the problem. Two dust materials were supplied especially for these tests by commercial concerns and the sprays were made from two well-known commercial products. A summer oil and a special spreader-sticker were included in some sprays.

The dusts were prepared so that a 2-pound application would be equivalent to a 15 to 20 gallon 10 parts per million spray application in the amount of growth substance present. Actually, 2 to 3 pounds of dust and 20 to 25 gallons of spray were used, depending mostly on tree size and crop. Standard sprays (.001 per cent) were used in most cases. Table I gives drop and related data for five treatments on McIntosh. There were eight mature trees per treatment.

TABLE I—EFFECT OF SPRAY AND DUST APPLICATIONS ON PREHARVEST DROP OF MCINTOSH

Treatment	Per Cent Drop (Means With Standard Errors)			Sep 8 to 17 Drop as Per Cent of Drop Prior to Sep 8	Average Tree Yield (Bushels)
	To Sep 8	Sep 8 to 15	Sep 15 to 17		
1. C. M.* No. 1 (.001 per cent)	8.7 ±1.79	5.4 ±1.33	6.4 ±1.48	130	20.7
2. C. M. No. 1 (.002 per cent)	11.3 ±2.80	2.3 ±0.46	4.5 ±1.30	65	14.5
3. C. M. No. 2 (.001 per cent)	8.6 ±1.73	1.5 ±0.35	4.8 ±1.07	73	21.5
4. Dust	8.7 ±1.44	6.0 ±1.04	6.7 ±0.88	140	19.4
5. Check	5.7 ±0.88	7.1 ±1.55	4.3 ±1.00	210	19.9

*C. M.—commercial material.

Sprays and dusts were applied on September 5 with an air temperature around 75 degrees F. Drops were picked up on September 8 and it is clear from the figures in the table that preharvest dropping had gotten well underway. Subsequent dropping was not heavy until the hot days of September 16 and 17 when control seemed to diminish rather generally. It is interesting to note that cooler weather on the 18th noticeably decreased rate of drop in other tests.

The sprays seemed to be more effective than the dust. Treatments 2 and 3 gave significantly better drop control than the dust treatment. Actually, the per cent drop figures show little beneficial effect from the dusting. But the fact that the check trees dropped less fruit up to September 8 would indicate that these trees were relatively not potentially bad droppers when compared with the test trees in general. If the drop after September 8 is compared with the drop before this date, it is seen that, after treatment, the dusted trees dropped 140 per cent and the check trees 210 per cent of the early drop. This method of calculation takes into consideration the natural dropping tendencies of trees which do vary greatly.

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[1] Contribution No. 424 from the Massachusetts Agricultural Experiment Station.

One commercial spray material seemed to be more effective than the other, this difference being counteracted by an increased concentration of the less effective material. Better drop control from the higher concentrations with McIntosh in Massachusetts has been reported (2).

Table II gives drop data from another orchard with 8 to 11 trees per treatment. Sprays and dusts were applied on September 5.

TABLE II—EFFECT OF SPRAY AND DUST APPLICATIONS ON PREHARVEST DROP OF McINTOSH

Treatment	Per Cent Drop (Means With Standard Errors)			Sep 8 to 19 Drop as Per Cent of Drop Prior to Sep 8	Average Tree Yield (Apples)
	To Sep 8	Sep 8 to 15	Sep 15 to 19		
1. C. M.* No. 1 (.001 per cent)	7.8 ± 1.16	3.7 ± 0.65	4.6 ± 0.60	112	1315
2. Same + 1 pint oil per 100 gallons	11.0 ± 1.70	3.9 ± 0.35	4.8 ± 0.88	85	1248
3. Dust	8.8 ± 1.73	5.9 ± 1.10	6.2 ± 1.21	146	906
4. Check	12.0 ± 1.65	8.6 ± 1.35	8.5 ± 1.10	141	1030

*C. M.—commercial material.

Here dusting was not effective in lessening preharvest drop. The sprays were somewhat effective.

The addition of a small amount of summer oil to the spray failed to improve control significantly in this case. Results in another test with a special sticker were as follows in per cent drop. Standard spray — 4.1 ± 1.30; standard spray with sticker — 2.6 ± 1.20; check — 14.7 ± 2.88.

In general, the results from spraying, as well as from dusting, were not outstanding in these tests. Dropping from check trees varied widely and was not as severe as uusal in many instances. It was always difficult and usually impossible to pick out the treated trees in the orchard on the basis of dropped fruit. In short, dropping was not as effectively checked as might be desired.

Results from a cooperative test with a grower indicated better control of drop with dust when the amount applied was increased from 2 to 4 pounds per tree.

EFFECT OF LATE APPLICATION

Some trees, which were sprayed and dusted on September 5, were utilized in a supplementary test to determine the efficacy of a late application. A commercial product was used at standard strength and a summer oil was included at the rate of 1 pint per 100 gallons of spray. Approximately 25 gallons of spray per tree were applied to seven trees on September 19. The air temperature was around 70 degrees F. Fourteen trees served as checks. Both sprayed and check trees were

TABLE III—YIELD AND PER CENT DROP BEFORE AND AFTER A LATE SPRAY APPLICATION ON McINTOSH

	Average Total Tree Yield (Bushels)	Per Cent Drop to Sep 22	Average Crop on Trees Sep 22 (Bushels)	Per Cent Drop Sep 22 to 26
Sprayed trees (7)	26.4	24.4 ±6.41	19.8	7.3 ±1.34
Check trees (14)	16.2	26.2 ±4.01	11.7	18.5 ±2.86

selected so that results would not be effected by any possible sustained effects from previous treatments. Table III gives drop comparisons both prior to and following the late spray application. The per cent drop up to September 22 is based on the total yield while the per cent drop from September 22 to 26 is based on the crop as of September 22.

It is evident that the late spray application reduced the preharvest drop of apples. The drop figures were reasonably close for the sprayed and check trees up to the time that the September 19 application became effective. During the following 5 days, dropping was significantly less from the sprayed trees. This is a further bit of evidence that hormone sprays, though applied rather late, may be effective in decreasing subsequent dropping of McIntosh. Southwick and Shaw (2) noted the same effect in 1940. This would seem to indicate that with many of the apples the changes resulting in abscission had not progressed far enough to prohibit the "hormone effect." Batjer and Marth (1) concluded that a repeat application on McIntosh was ineffective because of advanced abscission processes. It seems logical that the success of late spraying must depend somewhat on this very variable factor of "progress of abscission" of the apples remaining on the tree. Of course, the extent of the dropping before application may be the deciding factor in determining the feasibility of such a spray.

SUMMARY

The comparative effects of certain dust and spray applications on the preharvest drop of McIntosh apples is reported. Dusting was not as effective as spraying where, with each method, equivalent amounts of active ingredients were applied. Possible variability in effectiveness was noted between two commercial brands of drop-control materials. An increased concentration gave somewhat better control in one case. The results from the use of spreaders were not particularly favorable. A late application gave a significant reduction in subsequent dropping. In general, drop control was variable and often was not particularly marked, due in part to variation within treatments.

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Further Studies with Preharvest Sprayed McIntosh Apples[1]

By LYLE M. MURPHY, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

PREVIOUS studies by Gardner, Marth, and Batjer (2) and others as well as those at the Rhode Island Station in 1940 (3) have indicated that preharvest sprays on McIntosh did delay fruit abscission. The period of effectiveness on McIntosh was somewhat shorter than that on other varieties (1). Because of climatic variations from season to season, it is difficult to give any date as to when these sprays should be applied. The desirability of repeated applications is questioned especially if the fruit drop has started.

The purpose of this study was to determine as nearly as possible the best time to apply the sprays. The first spray application was to be made before any considerable quantity of apples had dropped. Another spray application was to be made to another group of trees 2 days later, and still a third application 2 days after the second application. By taking daily record of dropped apples, any difference that might exist among the three dates of spray application could be observed. The study further included the use of a repeat application treatment with a 4-day interval between sprays to determine if the period of effectiveness could be lengthened.

MATERIALS AND METHODS

A block of 72 McIntosh apple trees was divided into three groups of 24 trees, each group being sprayed on a different date. Each group of 24 trees was then subdivided into four plats of six trees, each plat receiving a different spray treatment. The trees were 22 years old and had an average crop of 10.2 bushels of apples per tree.

The pure chemical, naphthalene acetic acid, was used. It was first dissolved in ethyl alcohol, then diluted with water, and subsequently added to the spray tank. A power sprayer with a four-nozzle gun was used to apply the spray at a pressure of 400 pounds. A thorough application was applied to both the inside and the outside of the tree. The amount of spray material applied was about 1¼ gallons of spray per bushel of apples.

The apples from beneath all the trees were removed on September 5. There were very few sound apples on the ground at that time; for the most part, the dropped apples were either wormy or diseased. The first date of spray application was September 9, the next September 11, and the last September 13. Daily weight records were taken until the crop was harvested.

The climatic conditions experienced during the study were very mild. The mean maximum, the mean minimum, and the mean daily temperatures in the orchard during the study were 78, 55, and 66.3 degrees respectively. The mean daily temperature represented a deviation of 3.3 degrees above the normal mean for that time. The rainfall was .02

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[1] Contribution No. 617 of the Rhode Island Agricultural Experiment Station.

TABLE I—PERCENTAGE FRUIT DROP FROM McINTOSH TREES 12 DAYS AFTER SPRAY APPLICATION WITH FOUR TREATMENTS AND THREE DATES OF SPRAY APPLICATION, 1941 (SIX TREES TO A PLAT)

Treatments	Dates of Application			
	Sep 9	Sep 11	Sep 13	Mean*
Unsprayed	24.8	28.6	31.6	28.4
One spray, 5 parts per million concentration	5.6	13.6	9.3	9.5
One spray, 10 parts per million concentration	4.1	6.7	8.6	6.5
Two sprays, 5 parts per million concentration; 4-day interval between sprays	4.5	9.9	6.6	7.0
Mean†	9.7	14.7	14.1	——

†Difference needed for significance—3.6
*Difference needed to be highly significant—8.7

inches, and in general, there was little wind and considerable sunshine. Thus, it would appear that the favorable weather conditions may have had considerable influence on the results obtained from the study.

PRESENTATION OF DATA

The data in Table I show the average percentage of fruit drop from the six trees in each plat 12 days after spray application. The analysis by Fisher's analysis of variance shows that a difference of 8.7 per cent is necessary to be highly significant among the four treatments. The difference between the unsprayed plat mean and all three sprayed plat means is highly significant. No one spray treatment was significantly better than any other spray treatment. From the same analysis, the difference necessary for significance between the different dates of application is 3.6 per cent. The amount of fruit drop from the September 9 application is significantly less than the fruit drop from the other two dates of application. The interaction between dates of application and different treatments is not significant.

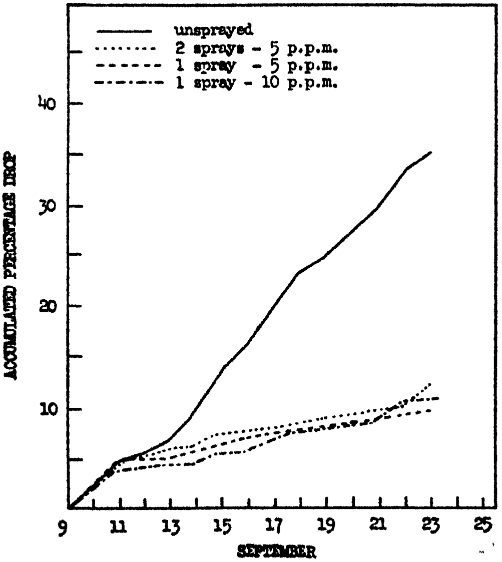

FIG. 1. Average accumulated percentage fruit drop for four treatments for 14 days after the September 9 spray application (6 trees to a plot).

A graphic representation of the accumulated percentage fruit drop for the four treatments after the September 9 spray application is shown in Fig. 1. It is evident from this graph that the repeat application treatment did not extend the effectiveness of the spray. However, the two-application treatment has advantages in that should the first spray application be applied too early, the second application would then compensate for the first application. Furthermore, the two-application treatment gives better coverage. Assuming that some apple stems were missed on the first application, it is reasonable that they would be hit on the repeat application.

Data comparing the accumulated percentage fruit drop of the 10 parts per million treatment for the three dates of application and the unsprayed treatment are shown in graph form in Fig. 2. This graph emphasizes the importance of proper timing. By delaying spraying from September 9 to September 13, a larger percentage of apples dropped by the time the September 13 application took effect than did in 12 days following the September 9 application.

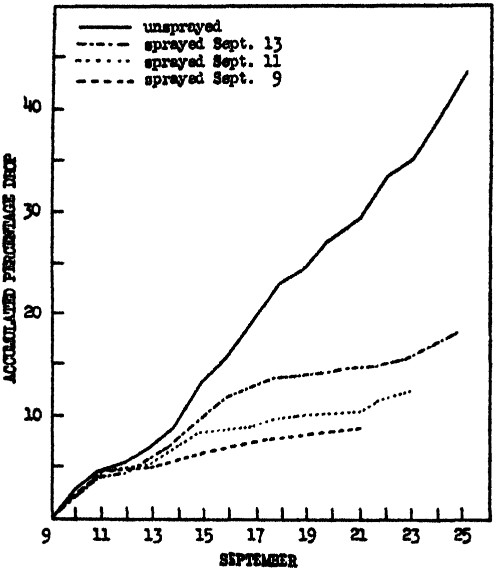

FIG. 2. Average accumulated percentage fruit drop of the unsprayed and 10 parts per million concentration for 12 days from the three dates of spray application (6 trees to a plot).

CONCLUSIONS

The results obtained with naphthalene acetic acid in a preharvest spray on McIntosh again delayed the fruit drop. The difference between the mean of the unsprayed plats and the means of all sprayed plats was highly significant. Thus, all three treatments were effective in reducing fruit drop.

The percentage fruit drop from the September 9 application was significantly less than the drop from the two later applications. This emphasizes the importance of proper timing of sprays.

While the repeat application treatment did not lengthen the effective period of the sprays, this treatment does have advantages, however. It gives better coverage and still delays fruit drop should the first application be applied too early.

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Temperature in Relation to Effectiveness of Preharvest Drop Sprays on Apples

By L. P. BATJER, *U. S. Horticultural Station, Beltsville, Md.*

THE comparative ineffectiveness of some preharvest sprays applied to apples in 1940 under relatively cool weather conditions suggested that the temperature prevailing during the drying period of the spray might have been an important factor. The present report contains results covering certain phases of temperature relationships with preharvest drop sprays.

EXPERIMENTS ON THE WILLIAMS APPLE

This experiment was conducted on a block of 15-year-old Williams apple trees located in the vicinity of Salisbury, Maryland. Spray applications were made July 10, 1941, to eight trees per treatment, randomized throughout the experimental block. The concentrations of naphthaleneacetic acid used, the time of day applied, and the prevailing temperatures are shown in Table I. The first color picking was made July 15, with the remainder of the fruit harvested July 18 and 21.

TABLE I—RELATION OF TEMPERATURE AND CONCENTRATION OF NAPHTHALENEACETIC ACID TO PREHARVEST DROP OF WILLIAMS APPLES (SPRAYS APPLIED JULY 10, 1941)

Treatment Concentration of A-naphthalene-Acetic Acid (P.p.m.)	Hour Applied	Temperature (Degree F)	Average Per Cent Drop			Average Per Cent Drop of Original Crop (S. E. M.)
			July 11 to 15	July 16 to 18	July 19 to 21	
1.25	1 p.m.	83	2.0	1.1	2.0	3.5 ±0.80
1.25	5 a.m.	63	3.3	1.6	2.6	4.8 ±1.02
2.5	1 p.m.	83	1.3	0.2	0.9	1.7 ±0.31
2.5	5 a.m.	63	2.0	1.5	2.2	3.7 ±1.22
5.0	1 p.m.	83	1.3	0.1	0.9	1.8 ±0.63
5.0	5 a.m.	63	1.4	0.2	0.6	1.8 ±0.41
Unsprayed	——	—	5.3	5.0	14.8	13.0 ±2.60

*July 10 to 21, inclusive, mean maximum temperature 83.5 degrees F; mean minimum temperature 66.6 degrees F.

The relatively cool weather that prevailed during the harvest period and the fact that the fruits were harvested as soon as sufficient color developed doubtless accounts for the low percentage of drop on the unsprayed trees (Table I), as compared with the same trees for the previous season (1). As is seen from Table I, all treatments were effective in significantly reducing drop. At the lower temperature (63 degrees F) the effectiveness of the spray seemed to increase with increasing concentrations, though the differences are not statistically significant. At the lower concentrations of naphthaleneacetic acid the effectiveness was greater when the sprays were applied at the higher temperature. The effect of temperature was more clearly indicated by omitting the July 18 picking on four trees in each temperature treatment receiving the 1.25 parts per million concentration. The fruit drop on these trees for the period July 15 to July 21 averaged 17.7 per cent ± 3.1 for the 63 degrees treatment, as compared with 7.1 per cent ± 2.1 for the 83 degrees treatment. At 83 degrees the 2.5 parts per million treatment proved just as effective as the 5 parts per million treatment; this latter concentration showed no difference in fruit drop at the two temperatures. No difference was obtained between 5 and 10 parts per million concentration of naphthaleneacetic acid applied to this variety in the same orchard in 1940 under average temperature conditions (1).

EXPERIMENT ON THE DELICIOUS APPLE

The nature of the treatments in this experiment and the date of spray applications are given in Fig. 1. Each treatment was applied to seven 16-year-old Delicious apple trees located in the station orchard at Beltsville and carrying a moderate crop of fruit. The sprays were applied on the date indicated at 6:00 a.m. and 2 p.m., with prevailing temperatures of 64 degrees F and 84 degrees F respectively.

It can be seen from Fig. 1 that both at 2.5 parts per million and at 5 parts per million concentration the rate of drop was considerably less when the spray was applied during midday at 84 degrees F than when applied in early morning at 64 degrees F. A concentration of 2.5 parts per million at 64 degrees F proved to be no better than the unsprayed treatment, while the same concentration at 84 degrees F was just as effective as 5 parts per million concentration at 64 degrees F.

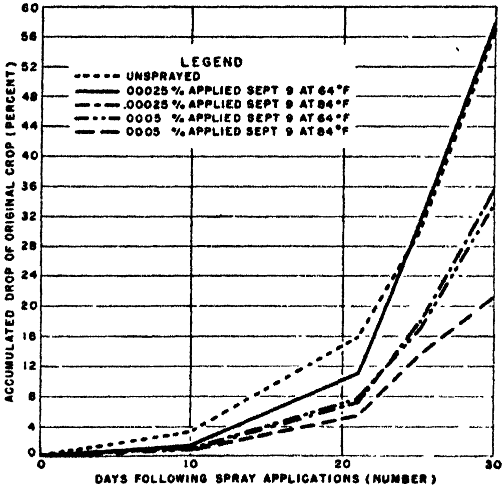

FIG. 1. Relation of temperature and concentration of naphthaleneacetic acid spray to preharvest drop of Delicious apples. Data represent an average of seven randomized trees per treatment. Difference in means required for significance 30 days after spray applications is 11.9 (analysis of variance 19:1 odds). The mean maximum and mean minimum temperature for September 8 to October 8, inclusive, was 85 degrees F and 60 degrees F respectively.

EXPERIMENT ON THE WINESAP APPLE

The relationship of temperature to effectiveness of preharvest drop sprays on the Winesap variety is presented in Fig. 2. Each treatment in this experiment was applied to eight 9-year-old trees located in one of the station orchards at Beltsville. Sprays were applied on the date indicated at 6:00 a.m. and 1:00 p.m., with temperatures of 63 degrees F and 82 degrees F, respectively.

In general, the results with Winesap (Fig. 2) are very similar to those obtained with Delicious. Five days after the treatments were applied, the trees receiving the 2.5 parts per million spray at 63 degrees F had dropped as many fruits as the check. As with Delicious, the

2.5 parts per million at 82 degrees was as effective as 5 parts per million at 63 degrees F. The limited effective period of the sprays in this experiment was perhaps associated with moisture shortage. During the period October 5 to 9 fruit growth rate was less than 25 per cent of its normal rate, and it was in the latter part of this period that very heavy drop occurred on all treatments.

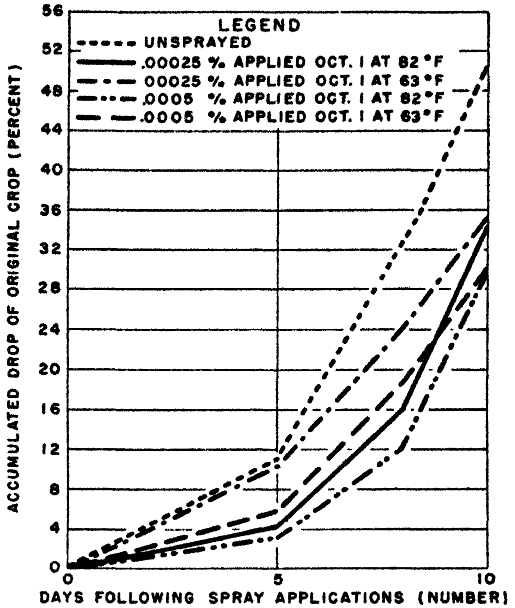

Fig. 2. Relation of temperature and concentration of naphthaleneacetic acid sprays to preharvest drop of Winesap apples. Data represent an average of seven randomized trees per treatment. Difference in means required for significance (analysis of variance 19 : 1 odds) 5 days following spray applications is 7.0. The mean maximum and mean minimum temperatures for October 1–10 inclusive, was 87.5 degrees F and 65.4 degrees F, respectively.

Experiment on the Stayman Winesap Apple

Concentrations of 2.5 and 5 parts per million applied at both high and low temperatures to 9-year-old Stayman Winesap trees at Beltsville, Maryland, failed to have an appreciable effect in retarding fruit drop. In this experiment moisture shortage was also very severe. Even though all trees showing visible signs of wilting were discarded, nevertheless, under conditions where growth rate of fruit was appreciably affected, fruit drop was heavy irrespective of treatment. In this same block of trees in 1940, with good moisture conditions, concentrations of 5 and 10 parts per million of naphthaleneacetic acid held fruit drop under 5 per cent for 3 weeks following application, and remained highly effective for more than 5 weeks (1).

Discussion

The results of these studies clearly indicate that naphthaleneacetic acid sprays applied in midday at relatively high temperatures were more effective at certain concentrations than when applied in early morning of the same day under cooler conditions. With the variety Williams, on which hormone sprays are extremely effective, these differences were obtained only when the concentration was below 5 parts per million. However, with both Delicious and Winesap, both 2.5 and 5 parts per million sprays were generally more effective when applied under conditions prevailing at the higher temperatures. Whether or not 10 parts per million sprays on the later varieties would have behaved similarly is not known. The data do suggest, however, an interrelationship between concentration and temperature and indicate the value of using higher concentrations on days or portions of days when the temperature is relatively low. If a limited amount of spraying is to be done, it would seem feasible to make applications during the warmer part of the day for greatest effectiveness.

The early-morning sprays generally required about 1 hour to become dry, as compared with less than 30 minutes for the midday sprays. The greater effectiveness of the latter suggests that absorption of the naphthaleneacetic acid solution was greater at the higher temperature despite the fact that the spray film became dry within 30 minutes after application. Aside from temperature, difference in suction tension of the tissues in early morning as compared with midday, might account for some of the differences obtained. However, limited suction tension measurements with apple have indicated even a greater negative pressure in early morning than later in the day.

Rather extensive studies were made to determine the effect of naphthaleneacetic acid sprays applied at different temperatures on the subsequent persistence of apple leaf petioles after removal of the leaf blade. Below 72 degrees F the rate of petiole drop increased with decreasing temperature. From 72 to 83 degrees little difference was obtained due to the increased temperature. While not directly applicable to fruit drop, these results suggest that approximately 75 degrees F may represent the critical point above which temperature may not be an important factor.

Experiments With Sprays in the Control of Preharvest Drop of Bartlett Pears in California[1]

By A. E. Davey, *University of California, Davis, Calif.* and
C. O. Hesse, *U. S. Department of Agriculture, Davis, Calif.*

EXPERIMENTS in the control of preharvest drop of Bartlett pears have been conducted during two years, 1940 and 1941.

In 1940 plots were selected in two orchards, one in Santa Clara County and the other in Lake County in the Clear Lake region. In some years in these areas the drop of fruit about harvest time is reported to be severe, but both the intensity and the dates of the onset of the drop seem to vary greatly with the season. In 1941 experiments were conducted in a single orchard located in Santa Clara County not far from that used the previous year and on similar soil classified as a Dublin adobe. This soil is sufficiently calcareous to cause some chlorosis in the foliage. The Lake County orchard is also on heavy soil with an alfalfa cover. All three orchards received ample irrigation. The two Santa Clara orchards were about 20 and 30 years old, and the one in Lake County about 10.

Experiment in Santa Clara County, 1940

Nine-tree plots were laid out in three blocks with random distribution of the treatments among the plots in each block. Check plots were protected by guard rows from spray drift from treated plots. Because there was a good deal of variation in vigor and the rows included some replants, the trees were classified as large, medium, and small.

Fruit started to fall in the first week of July. The growth-substance chemicals were applied in combination with a cover spray (3 pounds standard lead arsenate to 100 gallons) on July 9 after a considerable drop had occurred. Three materials were used: A-naphthaleneacetic acid, A-naphthaleneacetamide, and Fruitone (½ pound to 100 gallons) in a concentration of 10 parts per million for the active ingredient. Applications were made with spray guns using 300 pounds pressure. About 7½ gallons of spray material were used to the tree.

After spraying, the ground was cleared of fruits, the number of which was recorded, and thereafter counts on number of drops were made at intervals of 3 to 5 days. The crop was harvested on July 25, but it was not possible to get yield data. The number of fruits that dropped before the spray application was made, however, as shown in Table I, was assumed to be indicative of the comparative crops on these trees. The total amount of drop that occurred subsequent to treatment, including the fruit from all 27 trees under each treatment is also given. Analysis of variance of these data indicates an F value of 2.24 for difference between treatments, considerably smaller than the 4.76 value required for significance at the 5 per cent point. With elimination of the data for the small trees the differences in favor of treatment ap-

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[1] The assistance of the American Cyanamid Company and the California Spray Chemical Company in providing materials is gratefully acknowledged.

TABLE I—NUMBER OF PEARS THAT DROPPED IN SANTA CLARA COUNTY PLOTS, 1940 (TOTALS FOR 27 TREES UNDER EACH TREATMENT)

Treatment	No. Fruits Dropped Before Spray Application July 9	No. Fruits Dropped After Spray Application		Total Fruits Dropped After Spray Application
		July 10 to 12	July 13 to 25	
Naphthaleneacetic acid	885	254	2658	2912
Naphthaleneacetamid	947	238	1248	1486
Fruitone	834	271	2460	3002
Check	699	221	4310	4531

proach a significant level more closely, but are still somewhat short of significance at 19:1 odds. If, however, one uses only the data for the larger trees (Table II) as making a more uniform population and corrects by analysis of covariance for the tendency of individual trees to drop as shown before treatment, an F value of 13.32 for differences between treatments is indicated as against 5.41 required for 19:1 odds and 12:06 for 99:1 odds. A more closely selected population then shows greater sharpness in the differences but does not alter the trend of the results.

TABLE II—AVERAGE NUMBER OF PEARS PER LARGE TREE WHICH DROPPED BEFORE AND AFTER TREATMENT (SANTA CLARA COUNTY PLOTS, 1940)

Treatment	Number of Trees	Before Treatment	After Treatment
Naphthaleneacetic acid	17	39.3	135.6
Naphthaleneacetamid	13	45.3	73.0
Fruitone	19	38.3	132.0
Check	16	33.0	198.3

Difference necessary for significance: 46.43 fruits
F: 13.32
For 99:1 odds: 12.06

Considering the data for large trees only, it will be observed that the differences between the mean drop in plots treated with chemicals and that of the checks are greater than the difference demanded for significance. Also the drop after spraying with naphthaleneacetamid is significantly less than that resulting from the other two treatments.

The time that elapsed before the effect of the applications could be observed was 8 days, and it appears that the actual period required for the materials to take effect must have been greater than 3 days and less than 8. Once the effect was established it persisted at least until the counts were discontinued, 16 days after the sprays were applied.

EXPERIMENT IN SANTA CLARA COUNTY, 1941

In this trial the only material used was naphthaleneacetic acid in concentrations of 10 and 5 parts per million in a cover spray containing 4 pounds standard lead arsenate and 3 quarts summer oil per 100 gallons. Plots consisted of 11 trees. The treatments were replicated three times, with random distribution. As the drop was already well under way before the sprays were applied in 1940, the date of application in 1941 was changed to July 3 when very few pears had dropped.

At the time the spray was applied it was estimated that harvest would start about the same date as the previous year, that is, toward the end of the third week in July. However, harvest was later than anticipated, with the first picking on July 31, the remainder of the crop being picked on August 14.

Drop counts were made before harvest on July 25, July 28, and July 31, and before the second picking on August 14. Complete harvest data were secured, including the number of pears knocked to the ground by pickers (Table III). The drop is indicated as percentage of the pears on the trees at the beginning of the experiment. Analysis of variance of these data shows that differences as a result of the spray treatments were significant at the 5 per cent level (F = 12.6 against 9: 55 required for 19:1 odds). The difference between the drop in plots treated with naphthaleneacetic acid at the rates of 10 and 5 parts per million of spray solution was not significant, but significant differences between data from treated and untreated plots were obtained. It is interesting that the amounts of fruit knocked from the trees in the process of picking is roughly proportional to the set of fruit and shows no relation to difference in treatments.

TABLE III—EFFECT OF SPRAYING BARTLETT PEARS IN SANTA CLARA COUNTY IN 1941 (DISTRIBUTION OF CROP AS PER CENT)

Concentration of Naphthaleneacetic Acid in Spray (Parts per Million)	Crop as Average Number of Pears per Tree on July 3	Percentage of Crop		
		Picked	Dropped	
			Natural Drop	During Picking
10	929.5	87.1	7.4	5.5
5	898.8	86.8	8.7	4.5
None	886.3	80.1	15.8	4.1

For natural-drop data.
Difference necessary for significance: 5.3 per cent
F: 12.74
For 19:1 odds: 9.55

The estimated maximum crop on these trees amounted to 12.24 tons per acre. The plots sprayed with the naphthaleneacetic acid at concentrations of 10 and 5 parts per million yielded at the rate of 10.75 and 10.62 tons, respectively, and the untreated plots at 9.58 tons. Thus a saving of about 1 ton per acre was effected.

Because of the earliness of the spray application the distribution of

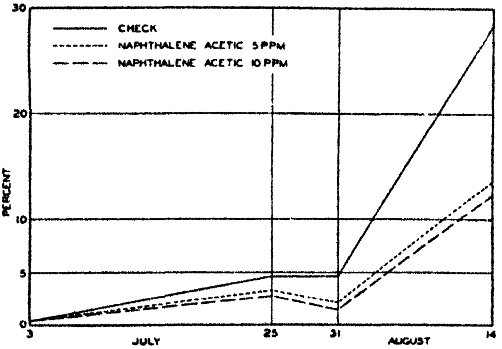

FIG. 1. Drop of Bartlett pears as per cent of fruits on trees at beginning of each interval between counts (Santa Clara County, 1941).

the drop throughout the experimental period is of interest. Fig. 1 shows the natural drop as percentages of the crop on the trees at the beginning of each interval between counts, and indicates very clearly that the ratios between the drop in the check plots and in the plots under each treatment were consistent during a period of 42 days, but that the rate of dropping markedly increased in all plots after the first picking date. There is some likelihood that the sprays in this experiment were applied too far in advance of the peak drop to obtain the most effective results. Whether or not a repeat application of the acid might have proved beneficial seems a moot point. The experience of Batjer and Marth (1) with Stayman Winesap apples indicated that sprays applied just prior to the beginning of drop were more effective than those applied 9 days earlier. With apples they found repeat sprays of value only when the initial sprays were applied too far ahead of the drop period.

EXPERIMENT IN LAKE COUNTY, 1940

Because the greatest part of the drop had occurred before spraying, the 1940 experiment in Lake County merely affords confirmatory evidence of the influence of the sprays on the tendency of the pears to drop. A heavy drop early in August attracted attention to this area and naphthaleneacetic acid at 10 parts per million and Fruitone at ½ pound to 100 gallons of water, but without arsenic or oil, were applied to 10 trees each. The trees in this orchard were selected for uniformity of growth, set of fruit, and size. Counts of drop were made once before spraying and three times after spraying, the last one being made after harvest. The data for this experiment are presented in Table IV. In spite of selection of trees for uniformity the ones treated with naphthaleneacetic acid started at a decided disadvantage relative to the other groups. For this reason and also because the larger part of the drop after spraying occurred before the chemicals became effective, the significance of the data is more clear when the totals of the drops occurring during the period when the treatments were effective (combining the counts made on August 13 and 29) are calculated as

TABLE IV—NUMBER OF PEARS DROPPED IN LAKE COUNTY PLOTS, 1940
SPRAYED AUGUST 5

Dates of Counts	Counts—Totals for 10 Trees		
	Naphthaleneacetic Acid	Fruitone	Check
Aug 5 before spray	1529	888	987
Aug 9 after spray	1071	705	644
Aug 13 after spray	136	112	281
Aug 29 after spray after harvest	282	155	445
Total after spray	1489	972	1370
Aug 5 count + Aug 9 count } A	2600	1593	1631
Aug 13 count + Aug 29 count } B	418	267	727
B/A per cent	16.0	16.8	44.5

percentages of the previous drop, or the totals for the counts made on August 5 and 9.

All three experiments reported here show that a period of more than 3 or 4 days was necessary for the expression of the influence of the sprays. The drop after treatment with chemicals at the strength of 10 and 5 parts per million was reduced to about 50 per cent of that from untreated trees, except that in one case where naphthaleneacetamid was used the drop was reduced to about 33 per cent of that in the checks. The use of this material, however, was not repeated. Strickland, Kemp, and Beare (2), encountering much heavier drop of pears (41 per cent of the crop at commercial harvest time) were able to reduce the loss to 25 per cent of that in the checks by using a heroic dose of 20 parts per million and three applications at fortnightly intervals up to harvest time.

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The Effect of Peat Moss on the First Two Season's Growth of Apple and Peach Trees Set in 1939 in West Virginia (Preliminary Report)[1]

By R. H. Sudds and Dillon S. Brown, *West Virginia Agricultural Experiment Station, Morgantown, W. Va.*

SEVERAL plantings of 1-year-old apple and peach trees were made in the spring and autumn of 1939 primarily for the purpose of testing the addition of German granulated peat moss as an amendment to the soil fill in the excavations in which the trees were set. Twelve quarts of the wet peat moss were incorporated thoroughly with all of the fill, including the surface soil, in the holes in which the treated trees were set.

The apple trees which were set only in orchard B were dug in a home nursery located in the orchard immediately before planting. All peach trees used in both orchards A and B were dug in commercial nurseries shortly before setting and then shipped by express to the orchards. Those for orchard A went into cold storage for several days while those for orchard B were heeled in for about one week.

In orchard A, the test site was on a slope of 15 per cent at an elevation approximately 1,500 feet above sea level. Sixty-four Halehaven peach trees were set on April 3, 1939, in Lehew fine sandy loam soil which was in virgin condition.

In orchard B, the test sites were on slopes of 3 to 4 per cent at an elevation of approximately 500 feet above sea level. Eighty-one Halehaven peach trees were planted on March 10, 1939, and 88 Winesap apple trees were set on April 13 of the same year. On November 26, 1939, 110 Staymared apple trees were planted. The soil in orchard B was of the Hagerstown series, chiefly a silt loam in texture.

With these four plantings of fruit trees in the Eastern Panhandle of West Virginia, two of apples and two of peach trees, set in two commercial orchards, each on a representative well-drained residual soil well adapted to fruit growing, no differences attributable to the use of the peat moss have been observed. The measurements taken included trunk circumferences, total branch elongations, and heights.

Peat moss should hardly be expected to show a beneficial effect with apple and peach trees on well-drained, well-aerated soils of reasonable fertility and in good physical condition, under the test conditions prevailing.

The ability to obtain further quantities of German peat moss prevented further tests of this material.

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Experiments with Sprays in the Control of Fruit Drop of Apricot and Peach[1]

By Claron O. Hesse, *U. S. Department of Agriculture*, and
A. E. Davey, *University of California, Davis, Calif.*

THE successful use of growth substances, especially naphthaleneacetic acid and naphthaleneacetamid, to control preharvest fruit drop of various apple varieties suggested the possible use of these substances to control early drop of stone fruit, especially apricot and peach. The Stewart apricot has a characteristic preharvest drop of a peculiar type, and under some conditions in the interior valley of California the Elberta peach drops badly during the harvest period. Tests to determine the efficacy of these substances in controlling preharvest drop of apricot and peach were made in 1940 and 1941.

Experiments with the Stewart Apricot and the Ideal Peach

The drop of the Stewart apricot begins about the time of pit hardening and extends to the time of fruit maturity, characteristically following the accumulative percentage trend for the check trees shown in Table I. About 25 per cent of the fruit may drop, although there is some variation from year to year, and from tree to tree in each year. After the drop is well initiated it proceeds rather uniformly until shortly before maturity, as is shown in the table. This drop is associated with embryo abortion, the cause of which has not been determined. The drop of the Ideal peach is very similar in its manifestation, starting rather early in the season and continuing uniformly and rapidly until fruit maturity.

In 1940 a small preliminary test on the Stewart apricot was made at Winters, California, consisting of nine trees in a Latin square arrangement. The trees were 13-years-old, vigorous, and bore a uniform moderately heavy crop. The trees showed some variability in size, owing to the difficulty of selecting a block bearing well, in a light-crop season. The trees were sprayed April 27 (soon after the commercial thinning) at the beginning of fruit drop, and again 2 weeks later, on May 8. Three trees were sprayed with a concentration of 10 parts per million of naphthaleneacetic acid, three with naphthaleneacetamid (10 parts per million), and three were left unsprayed, as checks. The chemicals were dissolved in 100 milliliter of ethyl alcohol and slowly added to the spray water. In addition, ¼ per cent light summer oil and ½ per cent blood albumen spreader were added to the spray to aid in penetration and coverage. The spray was thoroughly applied from a wheelbarrow-type sprayer, using 7½ to 10 gallons of spray to each tree. Dropped fruit was picked up at the time of the first spray and all fruit dropped subsequently was picked up at intervals of 2 or 3 days until harvest. At harvest yield records were taken and the number of fruits per tree were counted.

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[1] The assistance of the American Cyanamid Company and the California Spray Chemical Company in providing materials and equipment is gratefully acknowledged.

TABLE I—ACCUMULATIVE PERCENTAGE OF FRUIT DROP OF THE STEWART APRICOT SPRAYED ON APRIL 27 AND MAY 8, 1940, WITH 10 PARTS PER MILLION NAPHTHALENEACETIC ACID, WITH 10 PARTS PER MILLION NAPHTHALENEACETAMID, AND UNSPRAYED

Date	Naphthalene Acetic Acid		Naphthalene Acetamid		Unsprayed Check	
	Accumulated Per Cent	SE*	Accumulated Per Cent	SE	Accumulated Per Cent	SE
Apr 27	0.55	±.070	0.40	± .236	0.74	± .395
29	1.07	±.222	0.81	± .295	1.59	± .658
May 1	3.06	±.295	2.71	±1.599	2.93	± .140
3	4.20	±.302	5.08	±2.045	5.05	±1.606
6	4.88	±.338	6.41	±2.022	7.16	±2.095
8	5.62	±.240	7.65	±2.173	8.28	±2.342
10	6.14	±.279	8.68	±2.538	10.37	±2.789
13	6.69	±.400	9.46	±2.621	13.89	±2.993
15	6.86	±.315	9.76	±2.681	16.49	±3.144
17	7.10	±.351	10.00	±2.669	20.08	±3.463
20	7.23	±.246	10.04	±2.637	22.02	±3.703
22	7.41	±.310	10.12	±2.596	23.30	±3.993
24	7 76	±.464	10.42	±2.694	24.17	±4.150
26	7.80	±.516	10.52	±2.639	24.63	±4.132
28	7.89	±.559	10.64	±2.584	24.76	±4.090
Jun 1	7.99	±.550	10.70	±2.529	25.02	±4.201

*SE—standard error.

The course of the drop during the experimental period is shown in Table I, as accumulative percentages, and in Fig. 1 as percentage of drop at the pick-up intervals. For a period of 10 days to 2 weeks after the initial spray was applied there was little benefit noticeable, although the trees sprayed with naphthaleneacetamid showed a decrease in the drop after approximately 1 week. Beginning at the time of the

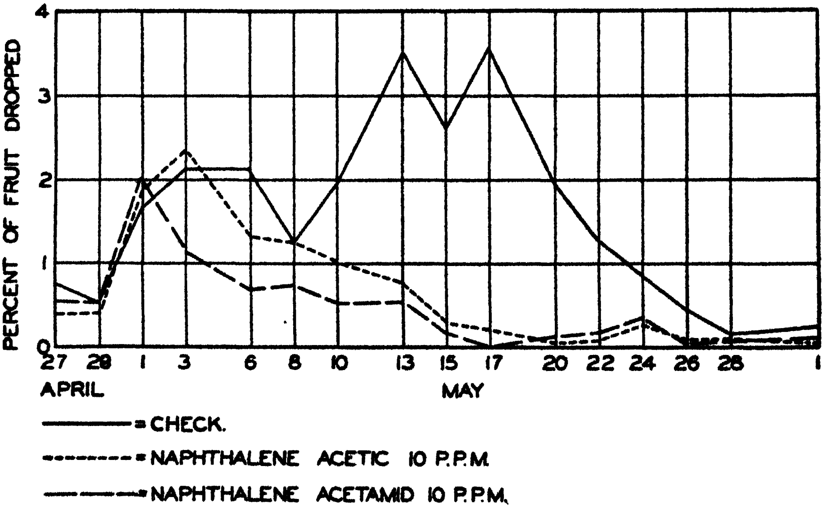

FIG. 1. Per cent fruit drop of Stewart apricot on trees sprayed with 10 parts per million naphthaleneacetic acid and 10 parts per million naphthaleneacetamid on April 27 and May 6, 1940. Pickups at intervals shown for the period April 27 to June 1.

second spray, May 8, there was a marked increase in the drop from the check trees, whereas the sprayed trees showed a decrease. From May 10 to May 25 the sprayed trees showed considerably less drop than the check trees. The last few days the sprayed trees were dropping as few fruits as the unsprayed trees. It should be noted that the trend toward reduction in fruit drop on the sprayed trees was initiated before the application of the second spray, and that the differences obtained were due to the increased drop of the check trees. As substantiated in the 1941 experiment, to be reported later, the second spray cannot be held to have caused the decreased drop after May 8, although it may have been a contributing factor. During the period of May 10 to June 1 (the effective period of drop control), the sprayed trees dropped only 17 per cent as much fruit as the check trees, whereas over the entire period of the experiment (April 27 to June 1) the treatments were only about 50 per cent effective. The sprays were effective for at least 2 weeks after the second application, and presumably to the end of the experiment on June 1, when the fruit was harvested. However, the drop under the check trees fell to a low percentage during the last week, and the differences could not be assigned significance.

In 1941 the test with the Stewart apricot was repeated on a much larger scale, and under such conditions as would have to obtain to give economical control. For this purpose a block of 24 rows, each 5 trees long, was selected. The trees were rather uniform in size, vigor, and crop, and the same age as those used the previous year. Alternate rows of five trees were sprayed with 5 parts per million naphthaleneacetic acid. The chemical was dissolved in ethyl alcohol and added directly to the spray tank without the addition of other materials. Although the trees were not thinned in 1941 because of the rather uniform moderate crop, the spray was applied as soon as it was possible to get in the orchard after the normal thinning time. The spray was applied on May 5, about 1 week later than desired. The spray was applied with a commercial spray rig at 350 pounds pressure, using a gun. The average amount applied per tree was 7½ to 8 gallons. Yield records were taken as the fruit was harvested, and the number of fruits per tree was calculated from the weight of fruit harvested from each tree.

Very little fruit dropping had occurred prior to the spray treatments. The ground was cleared of fruit immediately after the spray, and pick-ups were made at weekly intervals. Fig. 2 shows the course of the drop under these conditions. During the first week there was no material difference between the sprayed and unsprayed trees. During the second week, however, the sprayed trees showed a smaller percentage of drop than the check trees. At the end of the second week, May 19, the spray was repeated on half of the previously sprayed trees, using every other previously sprayed row. There was little difference in these two sprayed groups during the remaining week of the experiment. While the trees receiving two applications showed less dropping during the third week than did the one-application trees, it was not noticeably lower than the difference established the prior week for these two groups. Thus the slope of the curve indicating drop rate is very nearly the same.

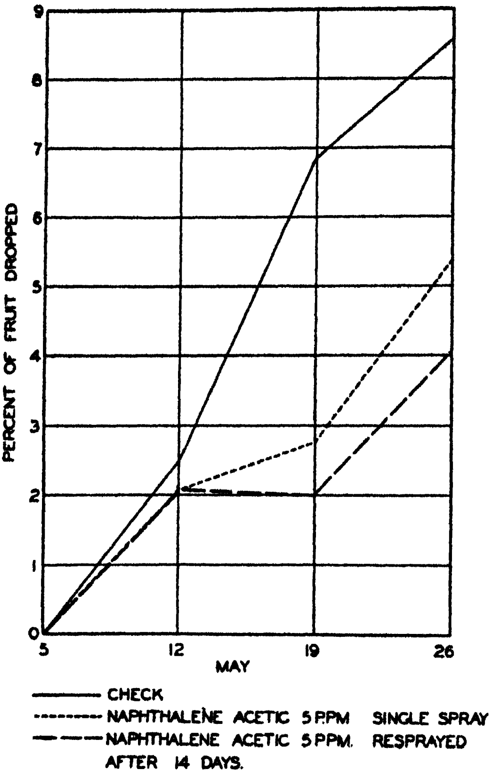

FIG. 2. Weekly per cent fruit drop of sprayed and unsprayed Stewart apricots, 1941.

The control of the drop was not as complete in 1941 as in 1940 and the effective period was not as great, even in those cases where the trees received two applications at a 2-week interval. However, this difference may well be attributed to the lower concentration of substance used, and possibly to poorer coverage.

Another Stewart apricot orchard of approximately the same age but of less vigor and bearing capacity was sprayed with ¼ pound of Fruitone per 100 gallons of spray (equivalent to 5 parts per million of growth substance). Five trees were selected as unsprayed checks in this block, each tree being paired with an adjacent sprayed tree of similar size and crop. The spray was applied May 6, using a single-nozzle gun attached to a power sprayer operating at approximately 300 pounds pressure. About 4 to 5 gallons of spray per tree were used. The results follow very closely those obtained in the larger block, so that no additional discussion is necessary.

In both 1940 and 1941 the Stewart apricot dropped approximately 25 per cent of the fruit left on the trees at the time of thinning. In 1940 the sprays reduced this to approximately 10 per cent, and in 1941 to 15 per cent.

The test with the Ideal peach at Davis in 1940 was very limited, as only two trees were available. One was sprayed with naphthaleneacetic acid at a time when the drop had started, May 29, and again on June 7, 15, and 22. The spray was applied at 10 parts per million, under the same conditions as for the Stewart apricot in 1940. About 10 gallons of spray were used at each application to carefully cover all the fruit. The general trend of the results was similar to that in the case of the Stewart apricot, except that the differences were not so pronounced, and the single-tree plots did not show enough difference to yield more than an indication of the effect of the spray.

EXPERIMENTS WITH THE ELBERTA PEACH

Under conditions existing in the interior valleys of California, the Elberta peach sometimes drops heavily at the time of maturity, especially where the fruit is left to reach canning maturity. In 1941 experiments were designed to test the effectiveness of growth-promoting substance sprays for the control of this drop, which is more comparable to that found in apples approaching maturity than that just discussed for the Stewart apricot. A block of 120 trees was selected at Red Bluff, California. In this experiment the fruit was allowed to reach a stage of maturity where most of the crop would be termed canning ripe. The trees were arranged in rows of 10. A plot consisted of two treated rows and a check row randomized within the plot. Four such plots were included in each treatment. The two spray treatments were naphthaleneacetic acid at 10 parts per million, with Vatsol OTC spreader, and Parmone at 1 pint per 100 gallons (equivalent to 10 parts per million). The trees were sprayed July 11, 1941, with a single-nozzle gun attached to a power rig operating at approximately 350 pounds pressure. This was estimated to be approximately 2 weeks before harvest, but actually harvest did not occur until July 31. The ground was cleared immediately after the spray was applied, for some drop had already occurred. The fruits were picked up and counted on July 29 and July 30. Table II summarizes the data, and shows that there was little difference in the sprayed and unsprayed plots. Yield records were not obtained, as it was felt that the evident uniformity of the trees and the relatively large size of the plots made it extremely improbable that the results would be materially affected if calculated on a percentage basis rather than as drop counts. It may be noted that the sprayed trees show a slight advantage over the checks, a condition that has always obtained, even though the results did not show significant differences.

TABLE II—NUMBER OF ELBERTA PEACH FRUITS DROPPED FROM PLOTS SPRAYED WITH 10 PARTS PER MILLION NAPHTHALENEACETIC ACID OR WITH 1 PINT PARMONE PER 100 GALLONS SPRAY, COMPARED WITH UNSPRAYED PLOTS (SPRAYED JULY 11, 1941)

Drop Period	Naphthalene-acetic Acid Plots				Parmone Plots				Unsprayed Plots			
	1	2	3	4	1	2	3	4	1	2	3	4
Jul 11 to 29	1160	1062	865	1054	1019	1322	1039	1147	1219	1324	1290	1243
Jul 29 to 30	92	163	53	55	104	84	114	61	72	166	98	53
Total before harvest	1252	1225	918	1109	1123	1406	1153	1208	1291	1490	1388	1296
Plot totals	4504				4890				5465			

Another trial with Elberta peaches was conducted in Merced County in the San Joaquin Valley. This rather old orchard was being rejuvenated and the trees were extremely variable, although all showed vigorous current growth and good foliage color. There were great differences in the individual tree crops, owing to loss of limbs by breakage and rot. The rows varied in number of trees from 8 to 10. Two sprayed rows and a check row constituted a plot. Five such plots were included in each treatment and were randomized throughout the block.

Naphthaleneacetic acid and Fruitone were applied as a fog-type (vapo-dust) spray to determine the possibility of using this method of application. Equal quantities of light summer oil and water were mixed in the spray tank, and a quantity of growth substance estimated to give a naphthaleneacetic acid application per tree equal to that in the usual water solution sprays at 10 parts per million was added to the emulsion. Thus 11.4 grams of naphthaleneacetic acid or 1½ pounds of Fruitone were added to 15 gallons of the oil and water emulsion. The sprays were aplied July 10, 1941. Approximately 10 gallons of material were distributed over 30 trees, or ⅓ gallon per tree. The check trees received the vapo-dust alone.

No drop had started at the time the sprays were applied. Pick-ups were made July 31 and daily or at 2-day intervals throughout the harvest period. Yield records were obtained, and the number of fruits per tree and percentage of drop calculated therefrom. The results are shown graphically in Fig. 3. At the time of the first pick-up on July 31, the sprayed trees held a slight advantage over the check trees, but no significant difference was found throughout the period of the experiment. For the total experimental period the sprayed trees showed slight advantage. There was little drop until a few days prior to July 31.

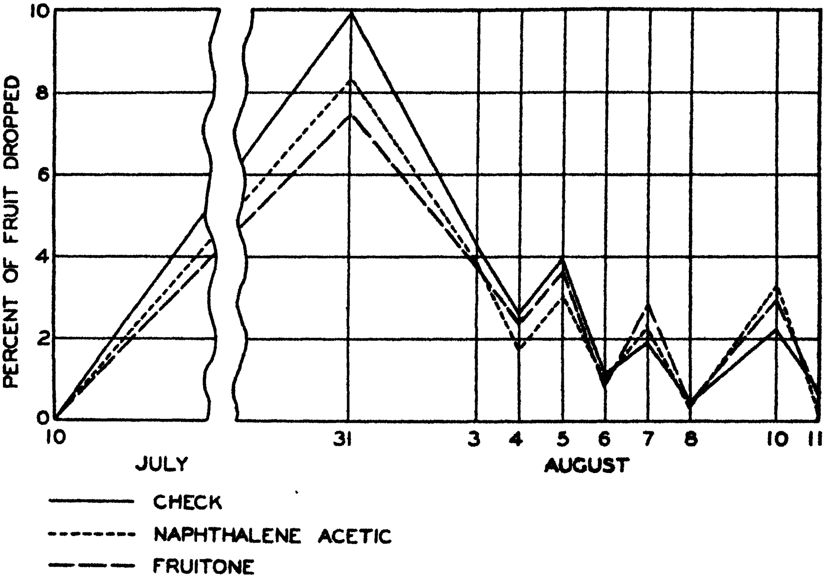

FIG. 3. Per cent of fruit drop from Elberta peaches sprayed with naphthaleneacetic acid and Fruitone (equivalent to 10 parts per million growth substance as water spray) 1941. Spray applied as vapo-dust.

It may well be pointed out that in this experiment the crop was being harvested throughout the period of records on drop, and some error results from calculating data on the basis of the fruit on the tree at the beginning of the experiment. However, all the plots were behaving similarly, so that such error is proportional and therefore does not affect the validity of the results. The real difference is that the apparently reduced rate of drop shown toward the end of the harvest period is actually a drop continuing at the same or a greater rate than previously. No attempt has been made to calculate the results on this sliding base, because of the small differences found, and because it was apparent in the field that no great value would accrue from such calculations.

The results of this experiment with the vapo-dust method of application do not differ in any material respect from those at Red Bluff with the water-spray method. Because of this lack of significant differences it is difficult to assign any advantage to either method of applying the materials.

In the case of the Red Bluff experiment the spray was applied after the fruit drop had already started, whereas in the Merced experiment the spray was applied some 2 weeks before there was any indication of drop. In each case the sprayed trees showed an insignificant advantage over the unsprayed checks. In the latter experiment this seemed to be due to a retardation of the drop in the early stages.

DISCUSSION

The use of the so-called drop sprays to control the preharvest drop of stone fruits has met with varying success, depending largely on the type of drop under consideration and upon the species treated. The anomalous type of fruit drop described for the Stewart apricot responded well to the sprays, although it is questionable whether they will be commercially economical. In these experiments the effect of the spray was much different from that described by various investigators for the apple. The most marked difference was the length of time necessary for the spray to become effective in stopping the drop. Under the various conditions of the experiments a period of 1 week to 10 days elapsed before a response was noticed. After this period the length of activity of the sprays varied, but seemed to be dependent upon the spray concentration, and possibly upon thoroughness of application. Thus, in 1940, with Stewart apricots, naphthaleneacetic acid and naphthaleneacetamide sprays at 10 parts per million resulted in very adequate control for approximately 3 weeks; while in 1941, for this fruit, a naphthaleneacetic acid spray at 5 parts per million effectively controlled the drop for 1 week only, even when a second application was made.

Both before and after the effective periods for the sprays the sprayed trees dropped fruit at the same rate as the check trees. The suddenness of the onset of control and the resumption of the rapid rate of drop was especially noticeable in the 1941 experiments with the Stewart variety.

The drop of the Elberta peach may be more nearly compared with the drop experienced with apple varieties. There are no apparent abnormalities, except that the fruit begins to drop from the tree before it reaches the proper stage of maturity for the planned use. Thus, in the orchard used at Merced, the 1940 crop was lost for canning purposes because most of the fruit dropped from the trees before reaching the proper stage of maturity. In 1941 the picking was extremely close to avoid a very large drop. The drop in the Red Bluff orchard was very heavy, as may be seen from the table. In both cases the sprays showed some effect on the subsequent drop, but the differences were very small. However, in these cases and others that have come to attention, there has always been some slight advantage to sprayed Elberta and other peach varieties exhibiting this late drop. In no case has the spray given differences great enough to suggest possible commercial use.

The difference in the type of drop in the Stewart apricot as compared to the Elberta peach undoubtedly accounts for the difference in response to the drop sprays. It is extremely interesting, in the light of the results obtained with apples, that the sprays did not greatly affect the abscission of normal Elberta fruits nearing maturity, whereas they did very greatly affect the abscission of immature apricot fruits that were going to drop, presumably because of an associated embryo abortion. The exact mechanism of abscission due to embryo abortion is not known.

A Comparison of Lime Sulphur and Flotation Sulphur Spray on Apple Trees[1]

By E. P. CHRISTOPHER, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

SPRAY materials have been checked in recent years for their effect on growth and yield as well as for their control of insects and diseases. Hoffman (4), Mills (5), Christopher (1) and others have reported various data dealing with this subject. For several years a flotation sulphur paste has been included in tests carried on at the Rhode Island Station. This wettable sulphur has the merit of being about as low priced as lime sulphur, and has, under our conditions been quite satisfactory in other ways. Certain comparative data involving this material and liquid lime sulphur are presented.

CARBON DIOXIDE ASSIMILATION

The influence of spray materials upon the carbon dioxide assimilation of apple leaves has recently received considerable attention. Hoffman (4) reported a marked reduction in assimilation when liquid sulphur 1–40 was used. Christopher (1) reported a smaller reduction from the use of flotation sulphur. Lime sulphur 1–50 is more generally used at present than is lime sulphur 1–40. Results reported last year by the writer (2) indicated that a reduction in concentration might produce less injury. Data comparing lime sulphur 1–50 and flotation sulphur, 16 pounds to 100 gallons, are given in Table I. The apparatus developed by Heinicke and Hoffman (3) was used for these determinations. The data represent 120 determinations under similar conditions before sprays were applied to one-half of the leaves, and 275 determinations after such treatments.

TABLE I—INFLUENCE OF LIME SULPHUR AND FLOTATION SULPHUR ON CARBON DIOXIDE ASSIMILATION OF MCINTOSH APPLE LEAVES (AVERAGE CO_2 ASSIMILATION PER 100 CM^2 PER HOUR)

Treatment		Average CO_2	Percentage	
			A/B	Reduction from Spray
Lime sulphur (14 leaves)	A*	8.25		
	B	5.45	66	35
Flotation sulphur (14 leaves).	A	8.98		
	B	7.51	84	18
Check—no spray (28 leaves).	A	8.88		
	B	9.02	102	—

*A = Determinations before any sprays were applied.
B = Determinations after sprays were applied to half of leaves.

It will be noted that the lime sulphur application reduced carbon dioxide assimilation about twice as much as did the very heavy application of flotation sulphur.

VISIBLE LEAF INJURY

Mature McIntosh and Rhode Island Greening trees were sprayed throughout the season with lime sulphur 1–50 and flotation sulphur

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[1] Contribution No. 615 of the Rhode Island Agricultural Experiment Station.

(Camden paste) 10 pounds to 100 gallons. About October 20th, 100 leaves on each of three trees for each treatment were examined for leaf injury. An estimate of the percentage of the leaf area showing injury was made, the results of this examination are given in Table II.

TABLE II—PERCENTAGE LEAF AREA SHOWING SPRAY INJURY (OCTOBER 1941)

Treatment	McIntosh	R. I. Greening
Lime sulphur (2 gallons to 100 gallons)	15.74	25.99
Flotation sulphur (10 pounds to 100 gallons)	8.72	3.68
Needed for significance		
Method of variance	2.76	2.78

These data show much more injury from lime sulphur on both varieties. The picture is not entirely fair however, since many of the most severely injured Rhode Island Greening leaves had already fallen to the ground. Almost no leaf fall had taken place with the McIntosh variety (see Figs. 1 and 2). Therefore, the true difference in favor of flotation sulphur would be greater.

Three-year-old McIntosh and Baldwin trees were subjected to the same spray treatments. In this case there were 25 trees of each variety distributed in five plots over a 2-acre field. An index of leaf conditions was taken October 29th, each tree being given a rating of 0 to 10 on the basis of its complement of leaves and their condition. Zero would

FIG. 1. Rhode Island Greening tree showing leaf fall from lime sulphur 1–50 (September 18, 1941).

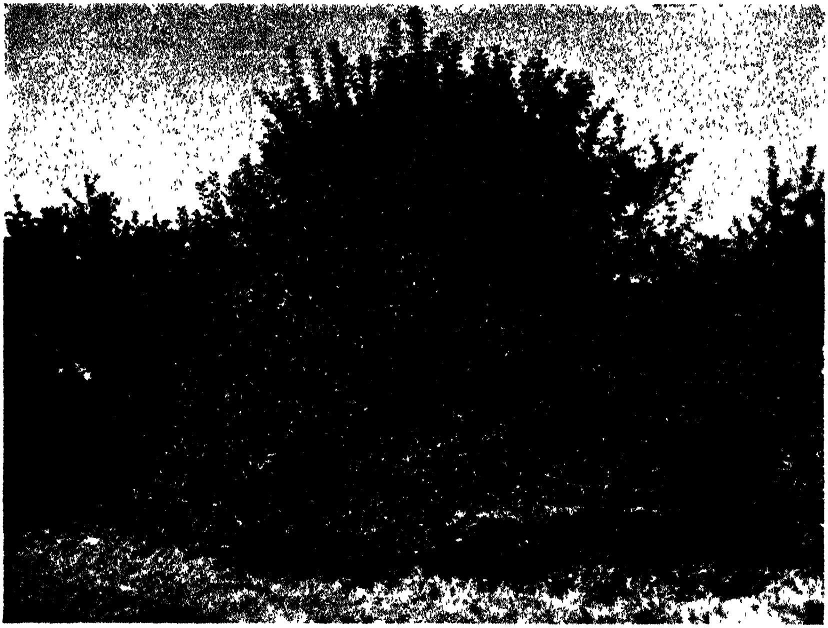

FIG. 2. McIntosh tree showing slight leaf fall from lime sulphur 1–50 (September 18, 1941).

mean no injury and 10 very severe injury. These data are given in Table III.

TABLE III—FOLIAGE INJURY INDEX FOR 3-YEAR MCINTOSH AND BALDWIN TREES

Treatment	McIntosh	Baldwin
Lime sulphur (2 gallons to 100 gallons)	3.7	6.2
Flotation sulphur (10 pounds to 100 gallons)	0.8	3.6
Check—no sprays	2.7	1.6
Needed for significance	—	—
Method of variance	1.1	1.7

Since these figures represent leaf injury from both disease and spray, a varietal difference as to both leaf injury and apple scab susceptibility can be seen. Lime sulphur produced nearly twice as much injury on Baldwin as it did on McIntosh. Apple scab was well controlled by both sprays. On the check trees nearly twice as much leaf injury occurred on McIntosh as on Baldwin — very largely apple scab. The year 1941 was very unfavorable to scab in Rhode Island or greater injury might have been experienced.

INFLUENCE ON TREE GROWTH

The same three lots of trees mentioned above were measured about a foot above ground to determine trunk diameter. Two measurements were made, one on the north and south axis and the other on the east and west axis, and the average diameter used. When strong shoots started below the one foot mark their area has been added in. These trees have been subjected to the same cultural treatment aside from spray. The data are given in Table IV and show that the flotation sulphur treatment is producing larger trees.

TABLE IV—Average Trunk Diameter of McIntosh and Baldwin Apple Trees Under Varying Spray Treatments (1941)

Treatment	McIntosh (Inches)	Baldwin (Inches)
Lime sulphur (2 gallons to 100 gallons)	1.87	1.98
Flotation sulphur (10 pounds to 100 gallons)	2.07	2.19
Check	1.91	1.89
Needed for significance	—	—
Method of variance	0.11	0.13

Yield Data

Only a few trees were available for yield comparisons but the data are presented to help complete the picture (Table V). With McIntosh there is a much lower yield on the lime sulphur trees but there was a difference in yield the first year of the test, 1936. The trend seems toward reducing yield but sufficient data to make a general statement are not available. In the case of the Rhode Island Greenings however, a marked trend toward reduced yield is apparent. While the number of trees is still small, the degree of difference suggests a response to spray treatment.

TABLE V—Yield of McIntosh and R. I. Greening Trees Sprayed with Lime Sulphur and Flotation Sulphur (Bushels)

Tree No.	McIntosh							Tree No.	R. I. Greening						
	1936	1937	1938	1939	1940	1941	Total		1936	1937	1938	1939	1940	1941	Total
							Lime Sulphur								
I-1	21.5	8.0	16.5	3.0	7.0	17.0	73.0	F-6	0.8	16.3	0.3	3.5	—	2.5	23.4
L-2	20.0	25.5	9.0	6.0	5.0	17.0	82.5	F-7	0.8	19.0	0.3	1.0	—	6.0	27.1
L-5	13.0	15.0	9.5	12.0	8.0	21.0	78.5	F-8	—	22.5	0.3	7.0	—	8.0	37.8
Average	18.2	16.2	11.7	7.0	6.7	18.3	78.0	Average	0.5	19.3	0.3	3.8	—	5.5	29.4
							Flotation Sulphur								
K-3	43.0	16.0	34.0	7.0	3.0	55.0	158.0	E-6	0.5	21.0	9.0	9.0	—	17.0	56.5
L-1	21.0	17.5	21.0	9.5	6.5	26.0	101.5	E-7	—	31.5	5.0	24.5	—	24.0	85.0
L-7	8.5	21.0	6.0	8.0	12.0	34.5	90.5	E-8	0.2	19.3	4.0	13.5	—	20.0	57.0
Average	24.2	18.2	20.3	8.2	7.2	38.5	116.5	Average	0.2	23.9	6.0	15.7	—	20.3	66.2

Stored Food

A preliminary check on the stored food in six McIntosh trees subjected to the two spray treatments was made. Twenty-five sections of terminal growth from each tree were made, stained with potassium iodine and examined for starch in the pith. This examination indicated about 13 per cent of the pith area filled with starch grains in the case of the lime sulphur trees, and 32 per cent in the case of the flotation sulphur trees. More extensive studies of this sort are being carried on.

SUMMARY AND CONCLUSIONS

A comparison of liquid lime sulphur and a flotation sulphur paste on both young and mature apple trees indicates the marked superiority of the later material from several points of view. Lime sulphur resulted in a greater reduction of carbon dioxide assimilation, less stored starch, more visible leaf injury, less tree growth and a smaller yield.

Flotation sulphur is a much safer material to use on apple trees than is lime sulphur. Laboratory results such as the gas analysis method of determining carbon dioxide assimilation, are supported by field data such as growth and yield records. From the standpoint of leaf injury, growth, and yield, flotation sulphur should be used in place of lime sulphur.

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The Effects of Bordeaux Mixture and Lead Arsenate on Apparent Photosynthesis and Transpiration of Pecan Leaves

By A. J. Loustalot, *U. S. Department of Agriculture, Brownwood, Tex.*

Abstract

This material will be published in full in the *Journal of Agricultural Research.*

STUDIES were made of the effects of Bordeaux mixture and lead arsenate applications on the rates of photosynthesis and transpiration of mature pecan leaves during the season of 1941. The Heinicke and Hoffman method (1) for carbon dioxide analysis was used for determinations of photosynthesis, and transpiration was measured by weighing the water given off by the leaves after it was absorbed by a dehydrating agent (pumice stone impregnated with sulfuric acid) through which the air was passed after passing over the leaves, and before it reached the carbon dioxide absorption towers. During the period from June 27 to July 28 three successive experiments were conducted with comparable pairs of dark green, healthy leaflets that had been sprayed with Bordeaux mixture, and two similar experiments with lead-arsenate-sprayed leaves were carried on from September 2 to October 10. Two determinations on each of two pair of leaves were made each day in all the experiments, one in the morning between 9:00 a.m. and 1:15 p.m. and one in the afternoon between 1:30 and 4:30 p.m.

Under the varying weather conditions which prevailed during the course of the experiments, no appreciable effects on photosynthesis or transpiration were obtained from one, two, or three applications of either Bordeaux mixture (6–2–100) and 8–8–100) or lead arsenate (6–100) to mature pecan leaves, even though the leaves receiving three applications were so well covered that the green color was hardly visible.

Wide fluctuations occurred in the rates of photosynthesis and transpiration from day to day, and during the morning and afternoon periods of the same day; but apparently these were due to changes in meteorological conditions since the ratio between check and test leaflets showed little or no significant deviation before or after the spray materials were supplied. The rate of photosynthesis was affected primarily by fluctuations in light intensity, while transpiration rates seemed to follow changes in temperature and relative humidity.

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Further Studies on the Effect of Common Spray Materials on the Internal Structure of Apple Leaves[1]

By WM. F. PICKETT and C. J. BIRKELAND, *Kansas Agricultural Experiment Station, Manhattan, Kans.*

ABSTRACT

This report will be published in full as a Technical Bulletin by the Kansas Agricultural Experiment Station.

THE purpose of the studies reported in this paper was to discover whether various spray residues affect the ratio of the internally exposed surface to the externally exposed surface of apple leaves to different degrees, and to determine at what stage in the development of the leaf the effect of the spray residues was greatest. Previous experiments have shown that the length of the palisade tissue is closely associated with the amount of internally exposed surface.

On February 24, 1941, 20 two-year-old trees of each of the Wealthy and York varieties were planted in a ground bed in a greenhouse. Within two or three days after the first new leaves began to appear, one-half of each of 10 trees of each variety was sprayed at weekly intervals with a spray composed of 2½ gallons of 33 degrees Beaume liquid lime-sulfur and 4 pounds of arsenate of lead in 100 gallons, and one-half of each of the other 10 trees of each variety was sprayed at weekly intervals with a spray composed of ¼ per cent Verdol summer oil spray and 4 pounds of arsenate of lead in 100 gallons. The other half of all 40 trees was left unsprayed.

Three days after the second, fourth, seventh, eighth, ninth, and tenth spray applications, leaves were collected from each tree, both sprayed and unsprayed portions, for microscopical study. At the tenth spray application, some hitherto unsprayed leaves 10 weeks of age were given this application and 3 days later the final collection of leaves was made.

Table I presents the measurements of total palisade lengths, in microns, of unsprayed and sprayed leaves for each variety, treatment, and collection.

The general trend of the data in Table I indicates that the spray applications prevented normal development of the palisade tissue of the apple leaves, gradually increasing the difference between unsprayed and sprayed leaves as the season progressed. Leaves which were 10 weeks old before they received a spray application were checked rather severely and held at about the value of the unsprayed leaves at the fifth collection, while those which were still left unsprayed continued to grow normally.

On April 2, 1941, 20 two-year-old trees of each of the Wealthy, Jonathan, and York varieties were planted outdoors. These trees were treated in the same manner as those grown in the greenhouse, except for the substitution of 2½ pounds of flotation sulfur for the oil. Leaves

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[1] Contribution No. 182, Department of Horticulture.

TABLE I—Depth of Palisade Tissue, Microns, of Sprayed and Unsprayed Greenhouse Grown Apple Leaves (1941)

Treatment	Leaves Collected After Spray Application						First Spray on Leaves 10 Weeks Old
	No. 2	No. 4	No. 7	No. 8	No. 9	No. 10	
		York					
Unsprayed	39	45	54	62	63	73	
Liquid lime-sulfur lead arsenate	36	47	48	49	55	61	65
Unsprayed	43	42	59	56	63	74	
Oil and lead arsenate	39	41	49	58	55	58	66
		Wealthy					
Unsprayed	55	79	98	104	110	115	
Liquid lime-sulfur lead arsenate	58	72	87	86	94	101	111
Unsprayed	63	75	96	98	104	115	
Oil and lead arsenate	60	68	83	87	96	99	105

collected after eight spray applications showed that the liquid lime-sulfur spray reduced the amount of the internally exposed surface more than the flotation sulfur.

This work indicates that spray materials shock or check normal cell development in apple leaves with each application, and that the so-called mild sprays do not have as great dwarfing effect as have the stronger materials.

The Effect of the Ground Water Table on Apparent Photosynthesis, Transpiration, and Growth of Stayman Winesap Apple Trees During the Growing Season of 1941

By David G. White and N. F. Childers, *Ohio Agricultural Experiment Station, Wooster, Ohio*

Abstract

This material will be published in full in an Ohio Agricultural Experiment Station Bulletin.

SIX 5-year Stayman Winesap trees planted 10 feet apart in the row were selected for uniformity in early spring. The root systems of five trees were surrounded vertically with galvanized sheet-iron to a depth of 30 inches in 10 foot squares. An impervious hardpan 30 inches from the soil surface formed a type of bottom for each tree compartment. Water was supplied through five sets of 4-inch tile which were sunk vertically to a depth of 30 inches within each square. An automatic watering system was devised to maintain the water table at the desired heights within the compartments. The foliage was partially developed on May 1 when treatments began. The following treatments were maintained until late fall:

Tree A' — Check — received only water from rains.
Tree A — Water table 10 inches from the soil surface.
Tree B — Check — received only water from rains.
Tree C — Flooded from May 1 to June 8.
Tree D — Check — received only water from rains.
Tree E — Water table 20 inches from the soil surface.

The Heinicke-Hoffman (1) apparatus was employed to measure transpiration and apparent photosynthesis. The activity of six leaves on each tree was determined on alternate days from 9 to 12 a.m. Linear growth measurements and average total leaf areas were recorded at 2 to 4 week intervals. No growth measurements were made on check tree A' because it was included after the other trees had been under treatment several weeks.

According to the common F-test of Fisher there were no significant differences between the rates of photosynthesis or transpiration per unit of leaf area for trees A', A, B, D, and E. Both photosynthesis and transpiration rates were significantly lower for tree C. On the basis of total leaf area per tree the leaf activities ranked as follows: Tree A, E, B, D, with tree C the least active. Total linear growth and total leaf area of the individual trees by the end of the season were in the same order as given above.

The data show that the greatest total amount of carbon dioxide was absorbed by the trees growing under high ground-water-table conditions. It is probable that the check trees did not receive adequate water from the soil for their greatest development and leaf activity. It is not to be intimated, however, that a high ground-water-table is recommended since other factors must be considered; for example, resulting succulency and possible winter injury, possible poor flower bud formation, and the effect of a natural lowering of the water table at some future date. Definite conclusions cannot be drawn until at least one more season has passed.

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The Effect of Manganese Sulfate on the Photosynthetic Activity of Frenched Tung Foliage

By WALTER REUTHER and FRED W. BURROWS, *U. S. Department of Agriculture, Gainesville, Fla.*

IN a previous paper (5) a disorder of tung foliage called frenching was described. The disorder is characterized by a partial interveinal chlorosis of the leaves. In advanced stages the tissue in the chlorotic areas may break down and form necrotic spots. It was shown that in the earlier stages these chlorotic areas could be restored to a normal green color by treatment with a dilute solution of manganese sulfate. The purpose of the brief study herein reported was to determine the effect of such treatment on the photosynthetic activity of this chlorotic foliage.

During the 1941 season frenching was quite prevalent in localized areas in numerous tung plantings in the north central part of Florida. No studies have been made which would indicate whether trees severely affected are greatly reduced in growth and yield of oil as compared to unaffected trees in the same area, or to manganese treated trees. Observations and a limited number of measurements suggest that severely affected trees have smaller leaves and less shoot growth than normal. With tung the yield factor is particularly difficult to evaluate because of the wide range of variability in inherent bearing capacity among individual seedling trees. It will require long term experiments involving well randomized and replicated field plots to indicate the effect of manganese treatment on the growth and yield of frenched trees.

METHODS

The trees used for this study were seedlings about 15 years old located in a large commercial tung planting west of Gainesville, Florida. Five representative trees were selected in a severely frenched area. Five pairs of non-fruiting terminals were selected on each tree. The pairs were matched on the basis of severity of frenching, exposure to light, size, and proximity on the tree. Only terminals well exposed to light were used for this study. At the outset of the experiment, the foliage of one terminal of each pair was dipped in a solution containing 1 per cent $MnSO_4 \cdot 4H_2O$ and 0.5 per cent $CaCO_3$, so that the leaves were thoroughly coated with a dark colored residue probably containing considerable quantities of manganese in the oxide form.

Simultaneous measurements of the rate of apparent photosynthesis were made on selected comparable leaves on the paired terminals (see Fig. 1). Thus comparisons of treated and untreated leaves were always made under comparable external environmental conditions. Two or three sets of measurements or "runs" of 3 or 4 hours duration were made each day. The apparatus used was a portable modification of the type developed by Heinicke and his students (1, 3, 4). The mercury pumps were powered by a small gasoline motor. The apparatus had six absorption towers, so that four were attached to assimilation chambers, and two were air blanks. The details of the technique used

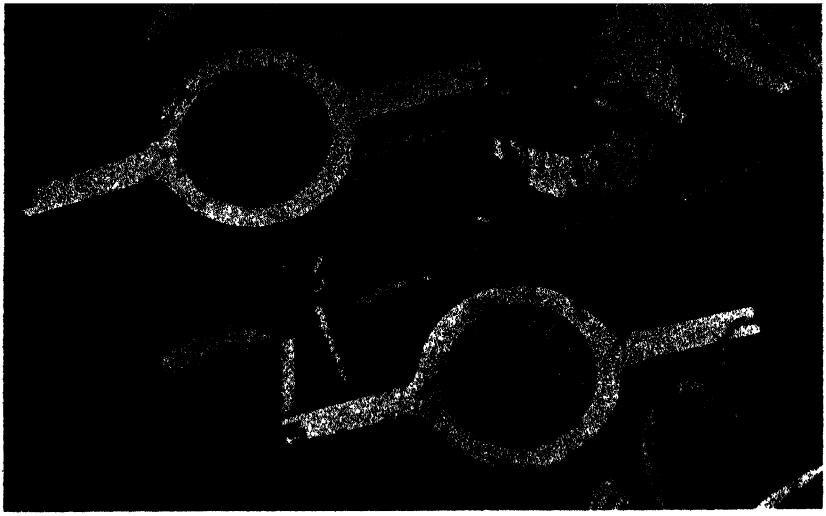

FIG. 1. Photograph showing a pair of shoot leaves inclosed in the Heinicke assimilation cups. This illustrates the pronounced difference in chlorosis between treated (upper) and untreated (lower) terminals which was obtained in some cases.

conform closely to those described by Heinicke and Childers (4), with the Heinicke cup (2) as an assimilation chamber attached to the lower surface of individual tung leaves. The rate of flow through the assimilation chamber was regulated so that it was about 2½ liters per square centimeter of leaf surface per hour. The total volume of air passing through an assimilation-chamber-absorption-tower system was estimated by calculation from the average of three flow measurements (corrected to standard temperature and pressure) made during the course of a run by means of a wet test flow meter. This method is not as accurate as using individual wet tests meters for each absorption tower, but the good agreement in CO_2 content found in duplicate air blanks indicated that the accuracy was adequate for comparative purposes at least.

EXPERIMENTAL DATA

The data presented in Table I indicate the effect of manganese treatment on the rate of apparent photosynthesis of frenched tung foliage. Weekly summaries of the data indicate that there was no effect of treatment during the first 2 weeks after the foliage was dipped (period I). During the next 2½ weeks (period II) there was no effect of treatment on the basal[1] leaves, but there was a significant stimulation of photosynthetic activity of the shoot[2] leaves. These data are in agreement with observations on the foliage conditions. There was practically no inter-

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[1] The first leaves to unfold in the spring, and which subtend the inflorescences or shoots which arise from the terminal bud.

[2] Leaves on the current season's shoot growth.

TABLE I—THE EFFECT OF MANGANESE SULFATE ON THE PHOTOSYNTHETIC ACTIVITY OF FRENCHED TUNG FOLIAGE

Type of Leaf	No. of Pairs of Terminals Compared	Treatment	Mean Assimilation*	Statistical Calculations		
				Odds†	L.D. for Sig. at	
					5 Per Cent	1 Per Cent
Period I—June 10 to 24						
Shoot	18	Manganese dipped	7.26	<19:1	2.40	3.30
		Check	7.24			
Basal	18	Manganese dipped	6.41			
		Check	6.68	<19:1	2.08	2.85
Period II—June 25 to July 11						
Shoot	18	Manganese dipped	8.68	>19:1<99:1	1.46	2.00
		Check	6.89			
Basal	19	Manganese dipped	6.79	<19:1	1.96	2.68
		Check	7.20			
Period III—August 4 to 12						
Shoot	25	Manganese dipped	7.95	>19:1<99:1	1.54	2.08
		Check	6.31			

*Mean of the rate of apparent photosynthesis expressed as mg CO_2 per 100 cm^2 of leaf area per hour.

†Odds that the difference between treatment means is significant as indicated by the ratio of treatment variance to error.

veinal chlorosis of the basal leaves, but the shoot leaves were quite generally affected to some degree. The frequency distribution of control leaves in the various classes indicated in Table II shows the marked difference in the incidence of chlorosis between basal and shoot leaves. These data also indicate the marked response of the more severely affected shoot leaves to manganese treatment. A third series of comparisons on shoot leaves only (Period III, Table I) gave further evidence of the stimulation obtained by manganese treatment.

TABLE II—A COMPARISON OF THE AMOUNT OF INTERVEINAL CHLOROSIS ON THE FOLIAGE OF MANGANESE TREATED AND CONTROL TUNG TERMINALS (19 DAYS AFTER TREATMENT)

Treatment (Applied June 10, 1941)	Type of Leaf	Total No. of Leaves*	Classes**					Index
			0 (Per Cent)	1 (Per Cent)	2 (Per Cent)	3 (Per Cent)	4 (Per Cent)	
Manganese dipped.......	Shoot	429	57.9	32.0	11.2	0.9	0.0	57
Control........		437	12.3	19.6	30.3	23.8	14.0	208
Manganese dipped.......	Basal	170	82.4	16.4	1.2	0.0	0.0	19
Control.........		160	65.0	31.2	3.8	0.0	0.0	39

*On a total of 25 terminals—five on each of five trees.

**The five classes represent progressively more severe stages of frenching, viz.: Class 0, none; Class 1, slight (estimated less than 10 per cent of leaf surface chlorotic); Class 2, moderate (estimated 10 to 25 per cent of leaf surface chlorotic); Class 3, severe (estimated 25 to 50 per cent of leaf surface chlorotic); Class 4, very severe (estimated over 50 per cent of leaf surface chlorotic or nectrotic).

†The summation of the products of the class number and the percentage in the class; hence the greater the index number, the more severe the interveinal chlorosis or frenching.

A fourth series of comparisons were made on paired leaves on the same terminal during the latter part of August and early September.

It was hoped that this technique, by eliminating the variability between terminals, would show more clearly the effect of manganese treatment. Unfortunately, in this case the controls as well as the treated leaves resumed normal green color, and there was no significant effect of treatment. It has been observed that this frequently happens in the latter part of the season. On a given tree, frenching symptoms may be fairly pronounced on the young shoot leaves early in the spring and summer, but by late summer or early fall, after terminal buds have formed, scarcely any chlorotic foliage may be found.

Discussion

The data and observations considered above do not suggest any very pronounced effect of manganese treatment on the rate of photosynthesis, or that frenching of tung is a very serious yield-reducing factor. However, it should be borne in mind that severely frenched trees may tend to produce small leaves. Thus it is possible that the total leaf surface is of more weight in determining the total photosynthate produced by a tree in one season than the efficiency of the leaf surface per unit area.

It might be surprising to some that partially chlorotic shoot leaves were not more strikingly less efficient than the manganese treated ones which had resumed a normal green color. In this connection it should be emphasized that the photosynthesis data summarized in Table I represent measurements made under the wide range of light and temperature conditions which normally occur in Florida during the summer months. Examination of the data in relation to the prevailing light and temperature conditions suggests that during the very cloudy weather associated with rains, light was the limiting factor for both chlorotic and manganese treated leaves. There also was some indication that during the hottest part of very bright days lower rates of photosynthesis were obtained than during the cooler parts of such days, suggesting that some factor such as high leaf temperature, solarization, or stomatal closure might frequently limit the process in tung foliage under field conditions in Florida.

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Further Studies on the Effects of Several Spray Materials on the Apparent Photosynthetic Rate of Greenhouse Roses

By M. T. Fossum and Alex Laurie, *Ohio Agricultural Experiment Station, Wooster, Ohio*

As a continuation of the investigations reported by Laurie and Witt (1), studies were made using the proprietary spray materials NNO, NNOR and Rotogreen.

Apparatus and method used for the tests was identical to that described for the above cited experiments except that the daily determinations were for 3-hour periods. For the photosynthesis studies six plants of the rose variety Better Times were maintained in a plot of haydite under hydroponic culture using the Ohio 2WP formula which was manipulated according to accepted practices. The sprays were applied in the eary morning of the days designated using all at the concentration of 1–400.

The use of NNO (technical mannitan monolaurate) gave an immediate reduction in apparent photosynthesis of 35 per cent in the first test. On the following day a 30 per cent reduction was recorded. By the second day after application there was no discernible reduction. From this time there were no further significant reductions until the sixth day after the first treatment when a second application was made resulting in an immediate reduction of nearly 20 per cent with complete recovery by the second day after treatment and no significant reductions thereafter. For this 15-day period the average light intensity was 615 foot candles and the average temperature 71 degrees F.

To confirm this first test and to find out if there was a latent effect from the spray, a second trial was made. In this instance the initial reduction was 35 per cent with 25 per cent being recorded on the following day. By the second day and for 8 days thereafter photosynthetic activity of the treated leaves was equal to that prevalent prior to spraying. The average light intensity for this 14-day period was 2960 foot candles and the average temperature was 80 degrees F.

A third test with NNO showed an initial reduction of 45 per cent. By the second day recovery was complete and permanent. For this experiment the average light intensity was 2950 foot candles and the average temperature was 88 degrees F.

NNOR (technical mannitan monolaurate plus 1 per cent rotenone and other derris extracts amounting to nearly 2 per cent) gave results somewhat similar to those for NNO. Fig. 1 depicts a typical representation of the action of two applications of this spray. In this instance the initial reduction was 70 per cent and a second application brought about an immediate reduction of 30 per cent. Two other trials gave initial reductions of 40 and 20 per cent, respectively. In each instance recovery was complete and permanent by the second day after treatment. Average light intensity and temperature readings were identical to those given for the tests on NNO.

The addition of derris extract to the mannitan cocoanut oil fatty

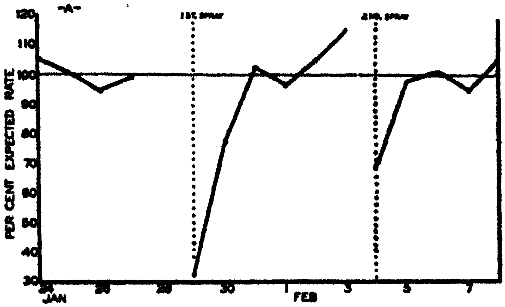

FIG. 1. The effect of two applications of NNOR at 1–400 on the rate of apparent photosynthesis of greenhouse roses.

acid derivative produces a synergistic effect, the combination being more effective than when either of the component parts is used separately. It is possible, then, that of NNO and NNOR, the more toxic of the two to insects might also bring about great reduction in apparent photosynthesis. The data suggest the probability of such a hypothesis.

The other spray material tested was Rotogreen. This is a compound of the rotenone and oil type composed of vegetable oils, trichlorphenoxyethylchloride, thymol, dibenzyl disulphide, phenothioxin, mannitan monolaurate and more than three per cent of derris resins. In the first test with this material there was a 65 per cent reduction in apparent photosynthesis. By the next day there was little reduction. Then for three days there were increasing reductions, such reduction amounting to 50 per cent on the fourth day after application. From this point on there was gradual recovery until the ninth day when recovery was complete and remained so until a second application was made on the twentieth day after the first treatment. This second application gave an initial reduction of more than 30 per cent with gradual recovery for two days followed by reductions varying from 20 to more than 30 per cent until the eighth day following treatment when a reduction of 43 per cent occurred. By the tenth day recovery appeared complete and stable. For the 35-day duration of this experiment average light intensity was 2900 foot candles and average temperature 80 degrees F.

In the second experiment with Rotogreen there was an initial reduction of 60 per cent and for two days following a reduction of 35 per cent was recorded. Then there were reductions of 10 to 20 per cent until the seventh day after treatment when there was a 25 per cent reduction. By the ninth day recovery occurred with no significant reductions on succeeding days. For the 17-day period of this experiment there was an average light intensity of 2900 foot candles and an average temperature of 83·degrees F.

It would seem that the initial reductions in these experiments must be in part due to mechanical injury from application of the spray materials.

Of the various materials tested under the given conditions on greenhouse roses the technical mannitan monolaurate alone or combined with rotenone has shown the least effect on carbon dioxide assimilation of the plants. Of the several sprays used to date in the apparent photosynthesis investigations of greenhouse roses, NNOR has proven to be the most effective as a control for red spider.

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Comparative Transpiration Rates of Peaches and Citrus

By Robert F. Cain, *A. & M. College of Texas, College Station, Tex.*

THE water relation of plants is one of the several basic plant functions which are of theoretical interest and practical importance. Numerous external and internal factors may affect the amount of water used by the plant. Sach (10) cites Stephen Hales as one of the earliest workers on transpiration. Later workers include Kiesselbach (9), Heinicke (7), Eaton and Belden (5), Hass and Halma (6), Kelley (8), and Cameron (4). Practically all of the work reported in the above papers have dealt with deciduous plants. More recently Hass and Halma (6) and Cameron (4) have investigated the transpiration rates of the genus *Citrus*. Hass and Halma (6) and Biale (1, 2), have used rooted citrus cuttings in their experiments while Cameron (4) used nursery grown trees.

Materials and Methods

In the study the following trees were used: four Marsh Seedless grapefruit trees, five Valencia orange trees, five South Haven peach trees, and three Texaberta peach trees. These groups of trees will hereafter be designated as Series I, II, III, and IV respectively.

The gravimetric method of determining water loss was used since it was felt that the plants would be least disturbed by using this method. The scales used were of the ordinary solution balance type of 20 kilogram capacity and were accurate to one gram.

The 2-year-old plants were placed in square 5-gallon tinned cans which contained 13.9 kilograms of air dry Lufkin fine sandy loam soil. Glass tubes used for the displacement of air and for the addition of water to the lower regions of the can were then inserted. Sufficient water was added to the containers to bring the soil moisture to 27 per cent by weight. The containers were then sealed and weighed.

The containers were placed in a small greenhouse for the course of the experiment. The ventilators were left open at all times to provide good ventilation. The greenhouse had previously been sprayed with lime which reduced the temperature inside to within two or three degrees of the outside temperature.

A self-recording thermograph and hydrograph were set on a small table at the height of the transpiring leaves. These two instruments were checked at regular intervals by the use of an accurate thermometer and a sling psychrometer. Evaporation data was obtained by the use of a Livingston porous cup atmometer which was also set at the height of the leaves.

The first few leaves on each branch were allowed to develop to the fullest extent, after which the growing tip was removed. All new leaves were removed as soon as they appeared; thus a relatively constant leaf surface was obtained. The total leaf area of each plant was calculated by tracing the outline of 50 representative leaves of each tree in a series upon graph paper. The area was then calculated by the use of a planimeter. The average area of the leaves was used as a basis to ascertain the total leaf surface in square inches. The leaves were not removed from the trees.

The measurement of water loss was started on July 18, 1940 and continued through August 17, 1940. The study was resumed on August 23, 1940 and was concluded September 15, 1940 (3).

Data were collected each day at 10 a.m. and at 4 p.m. Evaporation of water from the atmometer was first noted, then plant 1 of Series I was weighed, its loss of weight recorded, and sufficient water was added to return it to its original weight. The plants were handled in succession through plant 3 of Series IV. Before sealing, sufficient water was added to the containers to allow for the decrease in soil moisture during the 6-hour period from 10 a.m. to 4 p.m., at which time transpiration was the heaviest. The changes in the moisture content of the soil during these periods were not considered to be significant since not over 1.78 per cent of the available moisture had been removed.

On August 10 to 11 and August 24 to 25, 1940, readings were taken each hour for 24 hours beginning at 4 p.m. The following procedure was used in obtaining these data. The containers were brought to their original weight at 4 p.m. and enough water added to the atmometer to bring the level of the water in the burette to zero. At 5 p.m. the loss of water from the atmometer was noted and recorded. The loss in weight of the containers was then obtained, starting with the first plant in Series I and ending with the last plant in Series IV. This procedure was continued at hourly intervals until 10 a.m., at which

TABLE I—THE DAILY ABSOLUTE AND DAILY RELATIVE TRANSPIRATION OF THE PLANTS USED IN THE EXPERIMENT FOR A SIX-WEEKS PERIOD

Plant No.	No. of Leaves	Total Leaf Surface (Sq. In.)	Mean Daily Absolute Transpiration	Mean Daily Relative Transpiration
		Series I		
1	102	264.18	84	0.321
2	45	203.40	104	0.514
3	226	623.76	76	0.124
4	121	474.32	174	0.364
Mean	—	—	100	0.331
		Series II		
1	113	418.10	108	0.282
2	176	227.04	68	0.300
3	159	127.20	54	0.434
4	96	121.92	64	0.534
5	82	134.48	64	0.434
Mean	—	—	71	0.398
		Series III		
1	39	171.60	40	0.210
2	48	140.64	44	0.316
3	100	374.00	88	0.249
4	94	372.24	233	0.601
5	48	205.92	39	0.195
Mean	—	—	86	0.306
		Series IV		
1	67	149.41	128	0.881
2	147	225.78	368	1.632
3	165	453.75	321	0.708
Mean	—	—	272	1.136

time the atmometer and the containers were returned to the original volumes or weights. The above procedure was resumed at 11 a.m. and continued until 4 p.m., at which time the atmometer and the containers were again returned to their original conditions.

In the data reported in Table I, the mean absolute daily transpiration is the total amount of water loss per plant per day; the mean relative daily transpiration is the total amount of water loss for each square inch of leaf area per plant per day. These data are the average of daily determinations for a 6-weeks period.

DISCUSSION

According to Table I, the mean daily absolute transpiration of the Texaberta peach was over twice that of the South Haven peach. The mean daily relative transpiration of the two series varied proportionally. Apparently there is a difference between the density of the stomata, the capacity for the diffusion of water vapor, or the internal physiological or anatomical structures of the two varieties.

The mean daily absolute transpiration of the grapefruit was higher than that of the orange. The mean daily relative transpiration of these two types of plants varied in an inverse proportion. From Figs. 1 and 2, it is evident that the orange plants ceased transpiring 2 hours earlier in the evening than the grapefruit plants and resumed transpiration 1 hour later in the morning, thus shortening the transpiring period by

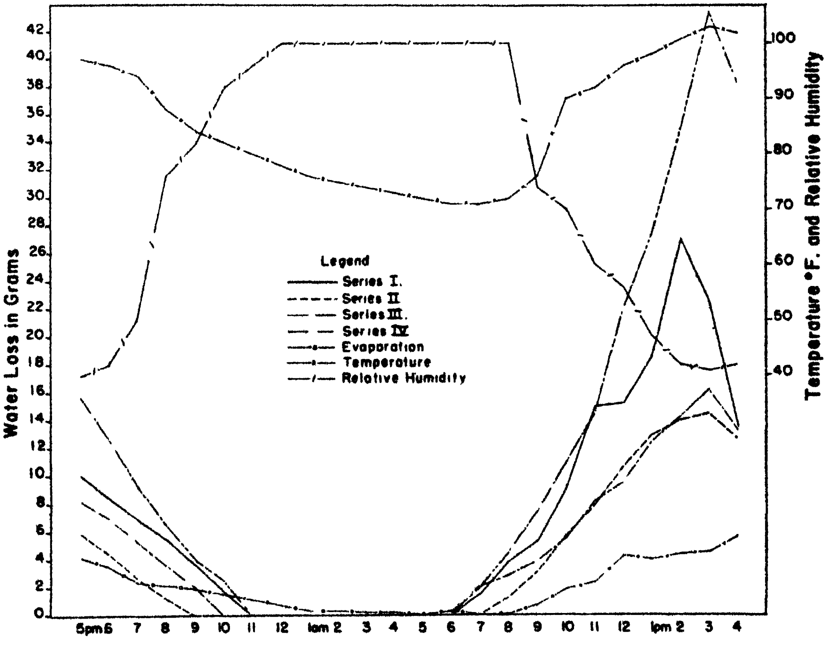

FIG. 1. Graph representing the average hourly rate of absolute transpiration for August 10 to 11, 1940.

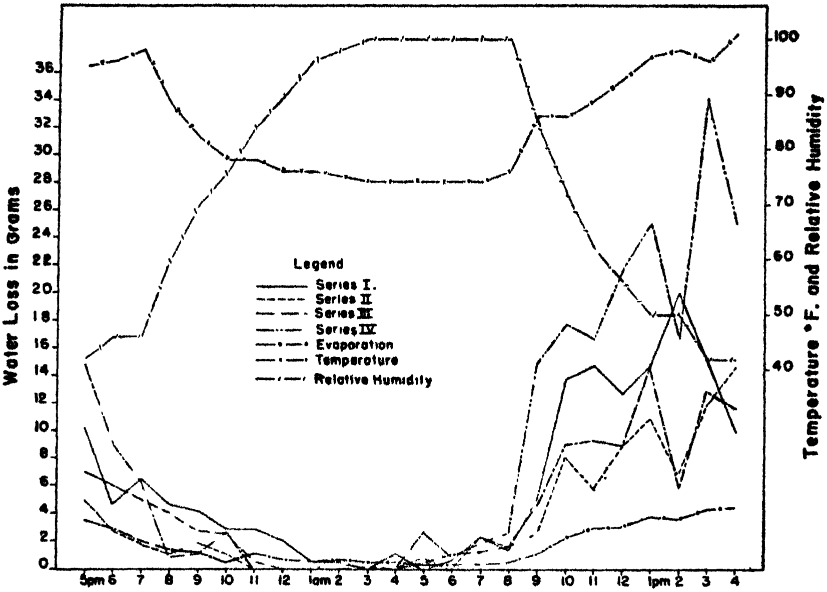

FIG. 2. Graph representing the average hourly rate of absolute transpiration for August 24 to 25, 1940.

3 hours. In the morning hours, the grapefruit started transpiring at the time of illumination while the orange did not start transpirational activity until 1 hour later. As is evident in the graphs, the curve of transpiration of the grapefruit ascends sharply upon illumination which is in agreement with Biale's (2) work on lemons, however this is not true with regard to the orange.

There was no evidence of such a distinct time of transpirational activity with the peach varieties as there was between the grapefruit and orange. Transpiration began at the same hour in the mornings, as evidenced in Figs. 1 and 2, but the cessation of transpirational activity in the evenings was extremely variable.

The grapefruit and the two varieties of peaches respond to light in a similar manner. The slowness of the response of the orange to light may be due to the necessity for greater intensity of light or to some internal factor which controls the opening of the stomates.

There was a general tendency in the grapefruit, orange, and Texaberta peach for the rate of relative transpiration to increase as the leaf surface decreased. This might be due to the ability of the plants with the smaller leaf area to maintain a more saturated condition of the walls of the transpiring cells, thus resulting in a higher rate of transpiration throughout a prolonged period.

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Notes on the Pollination of the Italian Prune

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THE Italian prune, sometimes designated as the Fellenburg prune, is the principal variety used for drying in Oregon and Washington and also leads the list of fresh prunes or plums grown in New York State for the market. There has been a recent increase in interest in the growing of the fruit based upon demand and upon the fact that many of the older plantings have been destroyed through age or winter injury.

In New York, the plantings for the most part, are set without definite provision for cross pollination. The fact that these plantings set good crops in some years indicates a considerable degree of self-fruitfulness. However, fairly frequently, the crops are light or almost a failure indicating that there is a pollination problem related either to a certain degree of self-unfruitfulness or to the effect of the weather upon the flight of insects or the process of fertilization.

Data on the pollination of the Italian prune are meager. Marshall (1) working in Oregon with emasculated blossoms demonstrated that the Italian prune was self-fruitful to a degree greater than most other varieties of *Prunus domestica* obtaining a 3 per cent set on 2,633 selfed blossoms. Irregularity of results obtained indicates that the technique employed was possibly not too satisfactory. Also the 3 per cent set on this variety would not be a good commercial crop, at least judging from the blossoming habit shown in New York. Marshall also demonstrated that the Italian prune would not carry fruit beyond the June drop if the embryo within was not developing normally. Wellington *et al* (2) stated that the Italian prune is self-fruitful but gives no data other than indicating there was a good set on selfed blossoms. His statement in the Bulletin is that the Italian prune is self-fruitful and a good pollinator for other domestica varieties. In 1928 the selfed blossoms set a higher percentage of fruit than the crosses. It is probable that emasculated blossoms were used in these tests. Allen (3) working in California showed in a pollination chart that the set on the Italian prune when selfed was poor but made no comment on the variety.

The work here reported was done to obtain further information on the self-fruitfulness of the variety and also as to the pollen value of several of the more recently introduced varieties, particularly the Stanley. The work was done on well cared for trees about 15 years old. The branch-unit method was used employing 3 by 6 feet cheesecloth bags to enclose branches about 1 inch in diameter. The bags were put on before the blossoms opened. The pollen was collected from branches forced in the greenhouse and applied to the blossoms with a small camel's hair brush. The results obtained in 1938 are given in Table I. The check branches which were bagged and brushed had the bags temporarily removed while the blossoms were open and the stigmas brushed with a camel's hair brush to spread the pollen. The checks not brushed were not disturbed after they were bagged. It is evident from the table that the variety is self-fruitful to a considerable degree,

TABLE I—SET OF FRUIT OBTAINED WITH DIFFERENT POLLENS ON THE ITALIAN PRUNE (BAGGED UNIT BRANCHES, ITHACA, N. Y.)

Treatment	Number Unit Branches	Average Blossoms Per Unit Branch	Number Fruits Per Unit Branch	Number Fruits Per 100 Blossoms
	Spring 1938			
Check bagged brushed	4	309	56.	18.3
Check bagged not brushed	2	369	48.	13.1
Check open	3	330	132.	36.7
Stanley pollen	4	225	56.	25.9
Imperial Epineuse pollen	3	189	55.	28.8
Standard Prune pollen	3	184	54.	20.3
Agen pollen	1	494	111.	22.6
	Spring 1939			
Bagged check not jarred	2	183	6.5	3.5
Bagged check jarred	4	298	22.0	9.4
Open check	6	134	66.3	51.4
Stanley pollen	4	163	17.5	11.4
Imperial Epineuse pollen	4	183	25.2	13.8

but that the set is decidedly improved by cross pollination with the other varieties tried. The open checks set much heavier crops than the cross pollinated bagged branches.

The Italian prune as grown at Ithaca produces relatively few blossoms as compared with many other domestica varieties and the blossoms are relatively inconspicuous being small and somewhat greenish. They are ordinarily borne singly or in twos and threes. On a tree with average bloom it would probably take a 25 to 30 per cent set to give a good commercial crop. Results obtained in 1939 are given in the second part of Table I. This year the check branches remained in the bags throughout the blooming period, the only treatment being that in the case of the jarred checks the bags and branches were shaken to jar the pollen loose and spread it around. The bag itself, of course, touched many of the blossoms and distributed pollen. This year the set inside the bags was less than in 1938 although the set in the open was higher. This result is probably related to the receptivity of the stigmas at the time pollen was applied. Again, considerable self-fruitfulness is indicated although cross pollination is a decided advantage. It is obvious that some agency is necessary to transfer the pollen from the anthers to the stigma other than jarring. The high set on the open checks compared with that on the cross pollinated bagged branches indicates that the blossoms in the bags were at a disadvantage. In no case was the set on the bagged branches equal to that on the open checks. Similar experiments were carried on in 1940, the data being approximately the same as those obtained in 1938. Data also show that the Imperial Epineuse is almost completely self-unfruitful.

It is recognized that these experiments and the data obtained are not sufficient to be used as a sure basis of generalization. It can be said that the Italian prune may be regarded at least as partially self-fruitful. The set can, however, be improved by cross pollination. All things considered, particularly the behavior of the trees in Western New York, it is indicated that care should be taken to provide bees for pollination especially in those areas next to the lake where good pollinating weather is likely to be inadequate. Although all the varieties tried as pollinizers gave an increased set over the selfed branches, it cannot be stated with certainty that the inclusion of pollen varieties would be profitable under all conditions. The inclusion of such varieties, however, would be an additional safeguard against crop failure in some seasons and might well be practiced, particularly in view of the fact that the Stanley is a good prune that will probably have a market value comparable to the Italian.

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Comparison of Certain Varieties as Pollenizers for the Delicious Apple[1]

By W. H. Griggs and A. Lee Schrader, *University of Maryland, College Park, Md.*

THE Delicious apple in Maryland is commercially self-unfruitful[2] (2) thereby requiring provision for cross-pollination. However, even with seemingly adequate provision for cross-pollination, Delicious under Maryland conditions exhibits erratic fruiting, conceivably due at least in part to the variable behavior of the pollenizers. For, despite the fact that many of our commercial varieties have been generally (Maryland and elsewhere) considered satisfactory pollenizers for Delicious, the inconsistency of experimental results indicates that variables have been present. Thus it seemed worthwhile to re-investigate certain varieties as pollenizers, particularly with an experimental design that would permit a statistical treatment of the comparative data. To this end pollination studies were conducted in 1940 and 1941.

In the spring of 1940 a study was made to determine the relative effectiveness of Golden Delicious, Williams, Winter Banana, Jonathan, Lowry, Yellow Transparent, Rome Beauty, Gallia Beauty, and York Imperial pollens, as well as open pollination in obtaining a set of fruit on Delicious. On May 4, 49 branches on eight 12-year-old Delicious trees were selected and each branch was enclosed with a cheese cloth bag, 3 feet by 5 feet. Ten of the 49 branches were selected from tree I so that each pollen source could be represented on this tree, while the remaining branches were distributed four to six per tree. A branch for open pollination occurred on each of the 12 trees and no pollen source was used on more than one branch on a given tree, although it was impossible to place any one pollen source on all trees. Unopened blossoms of the different pollenizer varieties were collected from May 4 to 7, and the anthers were shelled out and allowed to dry in Petri dishes. Pollen from the various varieties was applied with camel's hair brushes to the test blossoms during full bloom (May 8 and 9). Counts of the number of blossom clusters setting one or more fruits each were made on June 2 after the "June drop".

The mean per cent sets of fruits based on the total number of growing points, including vegetative points as well as those bearing flower clusters, and set of fruit based on the number of blossom clusters pollinated are presented in Table I. The calculation of the set of fruit on the basis of total number of growing points served to show the set from a commercial aspect irrespective of the bloom and also makes it possible to calculate the approximate leaf area per fruit, considering the consistent habit of Delicious to set one fruit per blossom cluster. Assuming an average of five leaves per growing point, a set of 20 per cent based on total growing points would mean 25 leaves per fruit,

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[1] Scientific Paper No. A26, Contribution No. 1836, Maryland Agricultural Experiment Station.

[2] In the spring of 1941, 917 clusters (about 4,585 blossoms) representing six Delicious trees were selfed by hand; only two fruits (0.0022 per cent) were set.

TABLE I—Comparison of Certain Varieties as Pollenizers for 12-Year-Old Delicious Apple Trees (1940)

Pollen Variety	For All Trees					For Tree I Only		
	Number of Branch Units	Total Number of Growing Points	Mean Set Per 100 Growing Points	Number of Blossom Clusters Pollinated	Mean Set Per 100 Blossom Clusters	Set Per 100 Growing Points	Number of Blossom Clusters Pollinated	Set Per 100 Blossom Clusters
Jonathan	4	623	23.7	516	28.3	22	112	29
Golden Delicious...	7	836	19.5	588	28.0	27	67	45
Winter Banana. ...	5	714	20.3	554	26.6	11	61	18
Yellow Transparent	4	474	17.2	370	24.8	10	122	12
Lowry............	5	548	19.9	385	23.0	39	93	42
Williams	4	571	16.8	462	19.5	21	80	25
Gallia Beauty......	4	599	11.6	407	17.3	11	67	15
York Imperial	3	323	15.1	304	16.0	8	102	8
Rome Beauty	5	522	11.1	385	15.2	9	100	10
Open Pollinated....	8	1,637	17.9	1,257	23.3	20	96	24
F value for pollen treatments			0.70		0.87			

which might indicate that a set of 20 per cent would represent a safe commercial set for Delicious necessitating only some light thinning to adjust for higher leaf area per fruit. From the low F values it is evident that there was no significant difference in set resulting from the different pollen varieties when based on either total number of growing points or the number of blossom clusters pollinated. Without statistical analysis one would be tempted to point out an apparent advantage resulting from the use of Jonathan, Golden Delicious, Winter Banana, Yellow Transparent, and Lowry as pollenizers, compared to Williams, Gallia Beauty, York Imperial, and Rome Beauty. Results from tree I only would have led one to favor Golden Delicious, Lowry, Williams, and Jonathan. The failure of the data to show differences in the efficacy of the different varieties as pollenizers for the Delicious apple, was, no doubt, partially due to the large error resulting from the large variability in set on replicate branches.

With the results of 1940 indicating the need for greater replication, the work in 1941 was outlined to have eight branch replications for each of five pollen sources, as well as eight open-pollinated branches. Accordingly, on eight 15-year-old Delicious trees, six branches were selected per tree which were used for a random placing of the five pollen varieties, York Imperial, Rome Beauty, Gallia Beauty, Jonathan, and Golden Delicious, leaving one branch per tree for open pollination. Since the season was earlier the test branches were bagged April 19 and 20 and the pollen from the various varieties applied April 22 and 23. Set counts were made May 25, immediately after June drop.

The mean per cent sets based on the total number of growing points, as well as of the number of blossom clusters pollinated, are presented in Table II. On the basis either of total growing points or of blossom clusters the mean per cent sets with Rome, Jonathan, and Gallia Beauty were approximately grouped in one class and were significantly higher than those obtained by Golden Delicious and York. It is interesting to note from the complete data (not presented) that Rome, Jonathan,

TABLE II—COMPARISON OF CERTAIN VARIETIES AS POLLENIZERS FOR 15-YEAR-OLD DELICIOUS APPLE TREES, 1941 (MEAN SETS FOR EIGHT BRANCHES)

Pollen Variety	Total Number of Growing Points	Mean Set Per 100 Growing Points	Number of Blossom Clusters Pollinated	Mean Set Per 100 Blossom Clusters
Rome Beauty	778	34.4	333	78.0
Jonathan	890	32.2	465	64.2
Gallia Beauty	786	30.4	374	63.0
Golden Delicious	558	17.5	443	39.7
York Imperial	982	14.2	446	34.2
Open Pollinated	2,134	20.3	802	49.4
Differences required for significance				
5.0 per cent level		10.7		18.6
1.0 per cent level		14.3		25.0
F value for trees		1.36		1.65
F value for treatments		5.23		6.52*

*Significant beyond the one per cent point.

and Gallia Beauty gave sets which were consistently high on each of the eight trees while Golden Delicious and York on these same trees were much more variable.

In order to test the validity of subjecting the set percentages to variance analysis these percentages were tested for homogeneity as outlined by Clark and Leonard (1). The Chi-square value obtained in the computation for the homogeneity test was not significant and, therefore, it was deemed safe to use the original percentages in the analysis and unnecessary to employ a transformation. However, for the sake of comparison the percentages were transformed to degrees by the transformation, $p = \sin^2 \theta$, (1) and tested for homogeneity. Since the Chi-square value obtained in the homogeneity test of the transformed data (degrees) was also not significant, the transformed data were analyzed and, in verification of the analyses of the percentages, showed no differences in the order of significance between the pollen varieties.

Comparing the results of the two seasons, the sets based on blossom clusters, were considerably higher in 1941 than in 1940 which can be largely explained on the basis of the inverse relation between amount of bloom and set, as by calculation the percentage of blossoms on all branches based on total growing points, was 76 per cent in 1940 and 45 per cent in 1941. The per cent set of fruit on the basis of total growing points ("commercial" set) was quite similar for both years, particularly with open pollination, which indicates an apparent advantage of this basis of comparison, avoiding in great part the inverse relation between bloom and set. On this basis, and assuming 20 per cent set as a safe "commercial" set for Delicious, it is apparent that in 1941 with pollenizers such as Rome Beauty (34 per cent), Jonathan (32 per cent), and Gallia Beauty (30 per cent), the set was well above the safe margin, whereas with Golden Delicious (17 per cent) and York (14 per cent) the set was not satisfactory, even though the set from these two pollen varieties based on blossom clusters was well above 30 per cent. From the 1940 data on "commercial" set, it is impossible to draw conclusions as to relative values of the pollenizers in this season, due to lack of significance; however, it is pertinent to note the small difference between open-pollinated "commercial" sets between the two seasons, showing lack of seasonal effects (lack of significance shown by statistical comparison of eight replicates in each season involving approximately 10,000 blossoms). In other words, it cannot be assumed from Tables I and II that the pollenizers behaved differently in the two seasons, but rather that lack of replicates in 1940 contributed to variable results in the 1940 season.

CONCLUSIONS

Contrary to general belief from previous work, the importance of proper selection of a pollenizer for the Delicious apple to avoid erratic fruiting appears to be evident, based upon an experimental approach to the problem in which adequate statistical analysis has been applied to pollination data for the first time. From these findings, it may be indicated for Delicious that Rome Beauty, Jonathan, and Gallia Beauty are superior, as pollenizers, to Golden Delicious and York Imperial and that the latter varieties may fail to give a commercial set on Delicious.

Further, in pollination work, the advantages of expressing fruit set in terms of per cent of total growing points have been brought out, especially in relation to practice, by translating the set of fruit in terms of a commercial set.

The value of a statistical approach to future pollination studies is indicated, and a re-evaluation of some previous results might be worthy of consideration.

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Pollenicides as Supplements for Bactericides in Blossom Blight Control

By E. M. Hildebrand and L. F. Hough, *Cornell University, Ithaca, N. Y.*

THE discovery that a dilute Elgetol spray functions as a pollenicide and blossom remover[1] in fruit trees (6) opened up a new approach to the horticultural problem of fruit thinning and at the same time to the control of the blossom blight phase of the fire blight disease.

The pollenicidal materials under discussion are practically non-bactericidal at the strengths used and repel pollinating insects by making the floral organs unattractive. This preliminary report is being published to invite criticisms and suggestions.

In order to gain information concerning the time interval over which pollenicides are effective in preventing fertilization and fruit set, experiments were planned using Elgetol and Nitrokleenup powder, a new material which laboratory germination tests had indicated to be promising as a pollenicide. Both of these materials completely prevented pollen germination on agar at a dilution of .0001, whereas at dilutions as strong as .02 they were only weakly bactericidal. The branch unit method described by MacDaniels (3) was used. The material was applied thoroughly with a knapsack sprayer, so that the blossoms and leaves dripped conspicuously.

The trees on which the two series of treatments with Elgetol were applied were in a depression and a frost the morning of May 12 killed all the open blossoms. A recording thermograph hung in the trees at the height of the bagged branches registered a minimum of 27 degrees F for 2 hours.

The Nitrokleenup sprays were applied to unit branches on five vigorous 10-year-old Rhode Island Greening trees that bore a normal crop of fruit in 1940 and blossomed quite full in 1941. The data obtained indicates a threshold level for Nitrokleenup under the conditions of the experiment. Since a large number of branches were selected on these five trees, all were not strictly comparable with respect to size and the amount of bloom but, since the unsprayed check branches included the entire range in the degree of blossoming, it is felt that valid comparisons can be made.

All the branches were hand pollinated on May 11 with Delicious pollen. Each treatment was replicated three times and the replicates were so arranged that no replicate, except the checks, occurred twice on the same tree. Also, since the trees were not large, all the treatments could not be applied on the branches selected in any one tree. These trees were in a different part of the orchard than the trees sprayed with Elgetol. A recording thermograph in a shelter near these trees registered a minimum of 31 degrees F the morning of May 12. No noticeable damage occurred to the blossoms. The temperature during the period of these treatments was relatively low. The official maximum and minimum temperatures at Ithaca for May 11 to 14 were, respectively, 58 and 35, 56 and 34, 67 and 32, and 71 and 37 degrees Fahrenheit.

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[1] The term "pollenicide" is used for materials like Elgetol which are highly specific for pollen inactivation. The same substances may also possess properties for penetration and host injury not necessarily implied by the term.

Only the data from the 0.1 per cent concentration of Nitrokleenup powder are presented (Table I) because the two weaker concentrations fell below the threshold level of toxicity. The criterion of fruit set before the "June drop" was adopted because it seemed to give a somewhat better picture of the effect of the pollenicide on the set of fruit than later counts. Although some variation occurred between replicates of the same treatment, it was felt that averages of the three replicates was a satisfactory figure for comparing the treatments. With so few replicates it would seem that small differences between the treatments were not significant. However, the marked decrease in initial set which was observed after spraying with 0.1 per cent Nitrokleenup powder at the time of pollination and 24 hours after pollination was mathematically significant and therefore can be taken as an indication that, under the conditions of this experiment, a 0.1 per cent concentration was effective in preventing fertilization and fruit set for a period between 1 and 2 days after pollination. A slight crinkling of the leaves on all the branches sprayed with 0.1 per cent Nitrokleenup was the only suggestion of injury in any of the treatments.

TABLE I—THE EFFECT OF NITROKLEENUP POWDER SPRAYED ON RHODE ISLAND GREENING APPLE BLOSSOMS AT DIFFERENT TIME INTERVALS AFTER POLLINATION UPON THE SET OF FRUIT ON BAGGED UNIT BRANCHES AT ITHACA, NEW YORK, 1941.
(SUMMARY TABLE)

Treatment	Number of Unit Branches	Average No. of Blossoming Points with Fruit May 29	Average Per Cent of Blossoming Points with Fruit May 29
Unsprayed Check	10	22.8	42.6
0.1 per cent at the time of pollination	3	11.7	20.2
0.1 per cent 24 hours after pollination	3	7.7	15.5
0.1 per cent 48 hours after pollination	3	20.7	38.4
0.1 per cent 72 hours after pollination	3	22.7	31.1

The data for the final fruit set corresponded quite closely to that taken before the June drop, except that there was somewhat greater variation. However, no marked changes occurred in the relative per cent of fruit set for the various treatments that would belie the observations made from the data taken before the June drop.

Evidence is accumulating that relatively safe strengths of Elgetol, as far as after effects on certain varieties of trees are concerned, are sufficiently potent for a marked thinning of the fruit in orchard trees (2, 7). In the former study on blossom thinning of Wealthy apple in 1941, Hoffman obtained good evidence that a single application of Elgetol (0.2 and 0.3 per cent) applied at full bloom performed a thinning job equal if not superior to hand thinning, judging by size, quality and yield of fruit and at less cost. Another benefit that may accrue from blossom thinning is a modification in the strong biennial bearing habit of certain apple varieties most of which are also subject to the blossom blight caused by *Erwinia amylovora.*

For a number of years the senior author has been devoting attention to the development of a control program for fire blight in apple, pear and quince based on the idea of prevention of infection. It is a well known fact that the most widespread dissemination of the pathogen occurs at blossom time, which makes the blossom blight phase the most critical period of the fire blight disease (1). Among control recommendations have been the removal of blossoms by hand from young trees before reaching bearing age and the spraying or dusting of bearing trees in bloom with bactericides to prevent infection. It has been repeatedly observed that the most severe outbreaks of blossom blight occur during the heavy bloom year in such biennial bearing varieties as Wealthy, for example. Moreover it has been shown (4, 5) that the first opened blossoms are the most apt to set fruit and under good pollination conditions 1 to 2 days are adequate for getting a commercial set of fruit. Further pollination is superfluous because it over-sets the trees with fruit necessitating thinning, and it also increases the fire blight hazard.

The build-up for severe outbreaks of blossom blight in fruit trees requires several days of weather conducive alike to insect activity and bacterial multiplication in blossoms. Although infrequent, when such favorable conditions obtain the bacteria from a single overwintering canker may, through the proclivities of pollinating insects, bring about an uncountable number of blossom infections.

In the experimental attack on this problem the importance of the time element cannot be over-estimated. Inoculum must first get from the oozing canker into open blossoms through the action of such insects as flies or by rain splashing. After multiplication in the relatively few blossoms thus inoculated further dissemination depends on pollinating insects. The time required for blossom infections to reach serious proportions will be variable depending on conditions, but it ordinarily occurs after the full bloom stage of blossom development has been reached. Bactericides such as bordeaux mixture (2–6–100) and copper-lime dust (20–80) to be effective must reach the blossoms ahead of the inoculum. The full bloom application was recommended on the basis of this experimental evidence taken over a period of years under New York conditions.

Only where the pollinating insects are imported can they be removed from the orchard environment. Thus the alternative idea of removing the late opening blossoms themselves suggests itself to the consideration of pathologists. In studying the potentialities of this technique certain basic investigations have seemed important. Pear and apple trees are most susceptible to blight infection during the first years of growth before reaching bearing age. In connection with such young trees pollenicidal sprays are being tested for removing all the blossoms, until the trees attain sufficient size for commercial crops, with promising results. These experiments will not be concluded for several years. Sprays on bearing trees to remove the late opening blossoms are also in progress, the design being to work in blight susceptible orchards both with and without a fruit thinning problem.

One of the basic investigations is concerned with the exact stage during the fertilization process following pollination when the blossoms become immune to the effects of the pollenicide (Elgetol). Evidence at hand from both published and unpublished sources indicates that under average temperature conditions fertilization takes place within 3 days from pollination. Studies to determine with more exactness the time intervals involved have not yet been concluded.

From preliminary observations it appears that the pollenicide performs its functions immediately after its application to the blossoms. It acts in two ways by inactivating the pollen on the exposed portions including the stigmas and anthers and also by penetrating and killing the outer portions of these organs. Shrivelling of the floral organs in advance of the bacteria thereby eliminates these organs as courts for infection by the fire-blight organism. It seems that the maximum distance of penetration down the style from the stigmatic surface, while somewhat variable, ordinarily falls short of the ovary region especially in the fertilized blossoms even with the more toxic strengths, since following the aplication only the part above the ovary discolors and shrivels. Such penetration down the style, by virtue of inactivating pollen up to a certain stage of penetration toward the ovary, makes Elgetol as a pollenicide effective over a longer period than bordeaux mixture as a bactericide because the latter must be on the blossom simultaneously with or ahead of the appearance of the bacterial inoculum to be effective.

Unfortunately, higher strengths of the Nitrokleenup powder were not used, so it is not definitely known whether a more concentrated application could be effective over a longer time interval. However, it is evident that a relatively weak concentration (such as 0.1 per cent) of this material does not penetrate deeply, since it was able to prevent fruit set at 24 but not at 48 hours after pollination. As has already been indicated, under certain weather conditions it might be highly desirable to use such a low concentration rather than a higher concentration that might cause a much greater reduction in fruit set. Furthermore from the results to date Elgetol seems to be a more satisfactory material than Nitrokleenup powder for such purposes.

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Thinning Wealthy Apples at Blossom Time With a Caustic Spray

By M. B. HOFFMAN, *Cornell University, Ithaca, N. Y.*

SEVERAL reports (1, 2, 3, and 4) have recently appeared concerning the possibility of spraying apple trees during the blooming season to reduce the set of fruit. The primary object of such work was to find a practical method of changing the bearing habit of certain biennial varieties so that the trees would bear their crops in what was the off years. Magness, Batjer, and Harley (4) have demonstrated that this can be easily done by killing part of the bloom at the delayed cluster bud or early pink stage. A dilute spray of either tar oil distillate or a prepared mixture of dinitro-ortho-cyclo-hexyl-phenol in oil was used.

MacDaniels and Hildebrand (2) reported that Elgetol, a product described by the manufacturers as containing the sodium salt of dinitro-cresol, was very toxic to pollen and would prevent fruit set when applied as a spray at concentrations of 0.1 to 0.2 per cent. Elgetol was used for blossom removal by MacDaniels and Hoffman (3) in several orchard tests in 1940. With neglected, non-vigorous Wealthy trees, an application of 0.2 per cent made at full bloom, destroyed the entire crop and resulted in only a moderate amount of injury to the young leaves. In spite of their low vigor, those trees blossomed full in 1941, while similar but unsprayed check trees failed to bloom. Thus, the bloom spray had changed the bearing year.

Merely changing the bearing year still leaves untouched one of the most serious problems in growing Wealthy, that of hand thinning to obtain size. Relative to the price received for other varieties such as McIntosh, Wealthy is considered a cheap apple. Yet, it is an expensive variety to grow because of the strong tendency toward biennial bearing and the necessity for heavy hand thinning. If a bloom spray could be applied so as to obtain some control over the degree of thinning, such a practice should reduce the cost of growing Wealthy, improve the grade, and contribute toward more regular bearing.

It was apparent from the 1940 tests that the amount of thinning accomplished depends on the stage of flower development, the vigor of the trees, the degree of self-fertility or sterility of the variety as well as the concentration of the spray and the thoroughness of the application. With these limitations in mind, several tests of blossom sprays were made in three commercial Wealthy orchards in 1941.

The first orchard was located in the lower Hudson Valley area of New York State. The trees were 17-years-old, very vigorous, well pruned and heavily budded. McIntosh and Delicious were interplanted in the block. The center blossoms on many of the Wealthy spurs were open on April 28. Warm weather prevailed for several days and the trees reached full bloom on May 1. Table I gives the results obtained when several concentrations of Elgetol were applied at different stages of bloom development. Ten trees were included in each treatment. The spray was thoroughly applied with a standard rig operating at 450 pounds pressure.

TABLE I—THE EFFECT OF ELGETOL APPLIED DURING BLOOM ON SET AND YIELD OF WEALTHY APPLES

Per Cent Concentration	Date Sprayed	Stage of Bloom	Ave No of Fruits Per 100 Blossoming Spurs	Ave No Bu Per Tree*	Ave No Fruits Per Bu*	Foliage Injury
Check	No hand thinning		47	15.4	182	—
Check	Hand thinned June 23		47	11.5	116	—
0.1	April 29	35 per cent	43	—	—	None
0.2	April 29	35 per cent	48	—	—	None
0.1	April 30	75 per cent	37	14.0	165	None
0.2	April 30	75 per cent	44	14.5	149	None
0.3	April 30	75 per cent	37	11.0	171	None
0.2	April 20 and May 1	75 per cent and full	22	13.5	119	Medium
0.2	May 1	Full	27	15.0	124	Slight
0.3	May 1	Full	14	13.0	100	Slight
0.4	May 1	Full	16	11.7	96	Medium

*Based on three average sized trees in each treatment.

All blossoming spurs on two representative unit branches of each tree were recorded at bloom time. The fruits on these branches were counted after the June Drop. From the data the average number of fruits set per 100 blossoming spurs was calculated for each treatment. Expressed in this way, 20 to 25 fruits per 100 blossoming spurs is considered a commercial crop for Wealthy.

Sprays applied on April 29 when about one-third of the flowers were open had no effect on the set of fruit. With more bloom open the following day some reduction in set was apparently obtained although the results are not consistent. This was probably due to the fact that the amount of flowers fully open varied for the different trees. All applications made during full bloom on May 1 reduced the set to that of about a commercial crop or slightly below. By this date many of the first flowers to open had probably been pollinated for a sufficient time to permit fertilization and prevent them from being killed by the spray.

Yield records were obtained from three average sized trees of each treatment sprayed on April 30 and May 1 as well as three unthinned checks and three checks that were hand thinned by the grower on June 23. At the time the hand thinning was being done the fruit on the trees sprayed during full bloom was almost ¼ inch larger in diameter than fruit on other trees.

A fruit count of 115 to 125 apples per box (1⅛ bushels) represents good commercial size for Wealthy. Apples of this size were produced by hand thinning and by spraying the trees with 0.2 per cent Elgetol during full bloom. The fact that duplicate sprays of 0.2 per cent applied on April 30 and again on May 1 did not reduce the set materially below that caused by a single application of the same concentration made on May 1 indicates that the first day of full bloom was the most satisfactory time to thin the crop under the conditions of this test. All the fruit produced with these treatments developed good color and graded U. S. No. 1 or better. Sprays of 0.3 and 0.4 per cent concentration at full bloom may have reduced the set too much. The apples were large but they were uniform in size, with fancy color and of excellent quality.

Those bloom sprays which resulted in the most satisfactory degree of thinning did not give quite as uniform distribution of fruit on all trees as did hand thinning. There were some doubles, and occasional small areas where the fruit was obviously too thick. A little hand thinning would correct this condition and assure fruit of the most uniform size. Observations on branches placed in the greenhouse December 10, 1941 indicate that all trees sprayed during full bloom have formed sufficient fruit buds for a full crop in 1942.

In referring to foliage injury the term "slight" means that the leaves were somewhat crinkled at the margins with occasional brown spots. "Medium" injury indicates a condition of distinct marginal burn. Most of the injury was confined to the small basal spur leaves. No injury of the spur tissue was observed.

As compared with the Hudson Valley area, the blossoming season in Western New York is usually several days later and generally extends over a longer period of time. This is due to the influence of Lake Ontario on the climate of the district. In 1941 the blossoming season in Western New York was exceptionally long. Some varieties required 7 to 8 days after the first flowers opened to reach full bloom.

Under these conditions blossom sprays were applied in a moderately vigorous Wealthy orchard located about 10 miles from Lake Ontario. A few of the center blossoms were open in this orchard on May 9 and it was estimated that 75 per cent of the bloom was open on May 11. Cool weather prevailed for the next few days and the trees did not reach full bloom until May 14. Even then about 5 per cent of the bloom was still in the balloon stage, most of this being on the terminals. The results are given in Table II.

TABLE II—EFFECT OF ELGETOL APPLIED DURING BLOOM ON THE SET OF WEALTHY

Per Cent Concentration	Date Sprayed	Stage of Bloom	Ave No Fruits Per 100 Blossoming Spurs	Foliage Injury
Check	—	—	52	—
0.1	May 11	75 per cent	51	None
0.2	May 11	75 per cent	42	Slight
0.1	May 14	Full	66	None
0.2	May 14	Full	30	Slight
0.1	May 11 and May 14	75 per cent and full	35	Slight
0.2	May 11 and May 14	75 per cent and full	13	Medium

Eight trees were used in each treatment. Unfortunately accurate yields were not obtained but it was estimated that trees averaged about 7 bushels each. The single spray of 0.2 per cent concentration applied on May 14 did not reduce the set quite enough. With a shorter blossoming period better results might have been obtained. However, these trees produced the best fruit in the orchard. In the opinion of the grower this fruit attained a better size and quality than fruit from unsprayed, hand thinned trees. Most growers do not thin Wealthy enough. The duplicated spray of 0.2 per cent concentration was the only treatment that seemed to reduce the volume of fruit below that of unsprayed trees. If the trees had been more vigorous, it is possible that this treatment would have proved more satisfactory under the conditions of the long blooming season.

About one-half of the bloom was open on May 9 in a vigorous Wealthy orchard located on sandy soil and protected on two sides by woods. Because of the cool weather the trees did not reach full bloom until May 13. On this date some petals were falling while a few of the trees still showed 5 to 10 per cent of the flowers in the balloon stage. Single applications of 0.1 and 0.2 per cent Elgetol were made to groups of 12 trees each on May 13 with the following results: checks, 85 fruits set per 100 blossoming spurs; 0.1 per cent concentration, 69 fruits and 0.2 per cent concentration 60 fruits. A single application under such conditions of blossom development did not reduce the set sufficiently to develop fruit of good commercial size.

When Wealthy trees are in a moderate to good state of vigor, 0.2 per cent Elgetol can be safely used as a spray to reduce the set at bloom time. No serious injury was caused by 0.3 or even 0.4 per cent on very vigorous trees. However there is no reason to use a concentration of more than 0.3 per cent when blossom killing is the only purpose of the spray. If no more than 2 days elapse between the opening of the first flowers and full bloom, a single application thoroughly applied during full bloom should destroy all flowers except the earliest ones to be pollinated and result in fairly satisfactory thinning of the fruit. When cool weather lengthens the period over which the flowers open to 3 or more days, two applications would probably be needed to reduce the set of vigorous trees sufficiently for the development of good commercial size. When two applications are used it would seem logical to make the first one 2 days after the first flowers open and the second at full bloom.

It should be emphasized that Wealthy is the only variety concerned in this report. Wealthy trees in a good state of vigor are quite self fruitful. Many varieties require cross pollination which would add other serious limitations to this practice. Some preliminary work with a few trees of Baldwin and Greening indicates that the foliage of these varieties might prove a great deal more susceptible to injury than that of Wealthy. This may be true with other varieties and especially in cases where considerable leaf area has developed at bloom time.

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How Long Does the Influence of Thinning Yellow Newtown Apple Trees Last?[1]

By G. G. Brown, *Hood River Branch Experiment Station, Hood River, Ore.*

YELLOW Newtown apple trees are characteristically alternate bearing in commercial orchards in the Pacific Northwest. Control measures have, for many years been approached experimentally from different angles, notably, fruit thinning, fertilization, pruning or, a combination of these. The problem is closely associated with such factors as leaf-fruit-ratios, time of thinning and vigor of trees.

Under average commercial conditions where a considerable proportion of thinning is performed from 50 to 70 days following bloom, bearing fruit spurs do not, with rare exceptions, develop fruit buds until the year following production. Dependence for annual cropping is placed upon the growth of an ample supply of non-bearing terminals either as very short fruit spur extensions or shoots which, under favorable conditions, develop one or more fruit buds which produce fruit during the following year. Where the per cent of bloom (in relation to the total number of growing points) and fruit set is high, trees are acutely predisposed to alternate bearing, particularly in the event fruit thinning is delayed and light in character. Trees at an early age, before attaining full development often become alternate bearing. During heavy cropping years, Newtowns make a greater average terminal growth than during light or non-cropping years. Terminal growth, during the "on" year, however, is characteristically "thin wood" being considerably smaller in diameter than that produced during the "off" year. The storage of carbohydrates appears to be associated with fruit bud formation. Roberts (1) reported "from the point of view of blossom formation, diameter of growth is a more important character than length. Slender growths are produced in the year when the tree is fruiting and thicker shoots form in 'off' years. This alteration in growth character is really the cause of biennial bearing as blossom buds form on growths of thicker diameter and less often on the very slender ones."

This report indicates the immediate and, apparently, carry over influence on yields of different thinning practices with full bearing Yellow Newtown trees which were about 30 years of age when first observations were made. Only one experimental thinning was given in 1934, the heavy cropping year. Annually thereafter, "commercial thinning" which consisted of light thinning to about 7- to 8-inch spacing between fruits after the "June drop", was performed. Variation in character of trees and of thinning done from year to year is recognized, but is not considered significant in the light of conclusions drawn during this comparatively long period. Annual winter pruning throughout was light in character. All trees under observation were subject to acute alternate bearing when the experiments were started.

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TABLE I—PRODUCTION OF YELLOW NEWTOWN APPLE TREES WHICH RECEIVED DIFFERENT THINNING TREATMENTS IN 1934 AND, DURING SUBSEQUENT YEARS, GIVEN "COMMERCIAL THINNING" AFTER THE "JUNE DROP", WITH 7- TO 8-INCH SPACING BETWEEN FRUITS

Experiment No.	Character of Thinning (1934)	Tree No.	Yields Per Tree (Loose Boxes)									
			Before Treatment		After Treatment							
			1932	1933	1934	1935	1936	1937	1938	1939	1940	1941
1	Unthinned	1	27	1	32.6	1.5	32	1	38.5	0	40	0
		2	26.9	4	31	6	28	5.5	36.2	2	37	4.6
2	6-inch spacing of apples	1	20	1	20.3	5.7	24	3.4	27	2	33.5	0
		2	19	2	19.5	7	23	4.6	23.6	3	29.5	2.6
3	"Bulk blossom" thinning*—3	1	29	.5	21.4	23.5	21.3	22.2	27.6	30.7	29	39.5
		2	36	.25	24.7	22	26.6	21	27.6	24.7	32.5	29.2
4	"Bulk calyx" thinning*—4	1	32	.5	20.5	23	27	19.9	28.7	21	28.2	22.3
		2	33	1.0	18.8	15.5	26.6	9.2	31	10.1	34.7	8.16
5	12 to 15-inch spacing of apples	1	30	.5	17.1	22.2	21	17.2	1.7	29	0	28.7
		2	33	0	19.4	24	29	21.8	29.9	24	23	16.1

*–3. All bloom removed from about one-half of tree; remainder thinned as in Experiment 2.
*–4. Thinned similar to Experiment 3 but performed at time of calyx spray.

CHARACTER OF EXPERIMENT AND DEFINITION OF TERMS

"Bulk blossom" thinning, (Table I, Experiment 3) refers to the hand removal of all bloom on April 4, 1934, from seven to eight large well distributed main limbs per tree, equal to approximately 40 to 50 per cent of the total bearing surface. "Bulky calyx" thinning (Table I, Experiment 4) was of similar character but done on April 20, when a calyx spray was being applied. Counts made within representative areas of trees given this character of thinning in 1934 indicate that from 80 to 90 per cent of all spurs produced bloom. The remaining portions of these trees were given a light thinning similar to that reported for Experiment 2. Preliminary experimental work of this character with Yellow Newtown as reported by Brown (2) was only partially successful in overcoming alternate bearing of this variety. Trees in Experiments 2 and 5 were thinned on April 20, to approximately 6-inch, and 12- to 15-inch spacing between fruits respectively. Trees in Experiment 1 were unthinned.

The completeness with which the alternate bearing habit of all limbs within the four trees given "bulk" thinning in 1934, was reversed in 1935, a character which has continued to the present time, is outstanding. Remaining areas within these trees which bore heavily in 1934, were nearly "off" bearing in 1935 and, likewise, with these limbs, nearly complete alternate bearing has continued to date. Thus, with two groups of limbs per tree, of nearly equal areas, each bearing fruit in an almost completely alternate manner, but in reverse order, the amount of fruit produced annually has been remarkably uniform one year with another. A record of the total number of apples and boxes produced annually from the respective portions of trees given different thinning treatments in 1934 and referred to as "bulk" thinned are available and will be published in a more complete report.

The data with respect to individual limb performance are consistent with the observations of Harley *et al* (4) who reported "that one or two main leaders on biennial bearing Newtown trees may show entirely different fruiting characteristics from the remaining portions of the tree, and each main leader appeared to function independently from the standpoint of the fruiting habit. This condition was found to have held constant over a period of several years."

Trees in Experiments 1 and 2, Table I, which were unthinned or received a uniform 6 inch thinning in 1934 continued production thereafter, in an alternate manner, the former very distinctly so. With those in Experiment 5, annual production was fairly uniform subsequent to 1933 particularly with tree 2.

Results of thinning Yellow Newtown trees during the "on" year, at dates ranging from 0 to 52 days following bloom are shown in Table II. Data for each experiment represent an average of two trees.

TABLE II—PRODUCTION OF YELLOW NEWTOWN APPLE TREES WHICH WERE THINNED IN 1934 TO 12- TO 15-INCH SPACING BETWEEN FRUITS AT DATES RANGING FROM APRIL 4 TO MAY 26, INCLUSIVE AND, DURING SUBSEQUENT YEARS, GIVEN "COMMERCIAL THINNING" AFTER THE "JUNE DROP" WITH 7- TO 8-INCH SPACING

Experiment No.	Days After Bloom	Average Yields Per Tree (Loose Boxes)									
		Before Treatment		After Treatment							
		1932	1933	1934	1935	1936	1937	1938	1939	1940	1941
1	0	26.4	1	18.8	20.5	15	18.7	7.7	22.5	0	23.7
2	15	20	2.6	13.9	17.5	22.5	18	20.1	17.5	19.2	17.2
3	27	21.4	.7	12.6	19.5	20.8	16.1	12.7	15	13	23
4	32	27.2	1	22	18.4	28	18.9	24.1	17	24.5	21.8
5	44	25.5	.25	18.2	8.75	25.5	7	32.2	3.5	37.4	2.3
6	52	28	0	25	15	47	9	48	0	54	0
7	Unthinned	25.6	2.6	31.6	2	27	5	35.2	0	45.5	0

Fruits were spaced 12 to 15 inches apart, one per spur. The results in the main, appear to indicate that early thinning has changed an acute alternate bearing performance to a more uniform one and that this favorable influence continued for several years thereafter. Trees thinned after 44 and 52 days were less favorably influenced in this respect. The data appear to be consistent with observations of Harley *et al* (4) who also reported that "heavy fruit thinning performed within 40 days of full bloom, brought both a high percentage of blossoms and fruit on main leaders the year in which they would normally have been entirely off."

Data given in Table III are an extension of and supplement to a preliminary report of the author (3) respecting blossom performance of Yellow Newtown terminal shoot growth in relation to alternate bearing, pruning and thinning of fruit. Trees in Experiment 1 were thinned in 1934, the "on" year, to one apple per spur, with about 6-inch spacing and those in Experiment 2, to 12 to 14 inches, with an average of 1.3 to 1.4 apples per spur. Since the more significant influence upon the bearing habit of trees in these tests appears to be the character of thinning done rather than that of pruning, the average performance of trees with respect to thinning only, are included herewith. The data again show that an acute alternate bearing habit was definitely changed to that of almost uniform annual bearing thereafter, as a result of one heavy thinning and, that this was only partially

TABLE III—PRODUCTION OF YELLOW NEWTOWN APPLE TREES WHICH WERE THINNED IN 1934 TO 6-INCH (EXPERIMENT 1) AND 12-INCH (EXPERIMENT 2) SPACING OF FRUIT AND DURING SUBSEQUENT YEARS GIVEN "COMMERCIAL THINNING" AFTER THE "JUNE DROP" WITH 7- TO 8-INCH SPACING

Experiment No.	No. Trees	Annual Average Yields Per Tree (Loose Boxes)											
		Before Treatment		After Treatment							Average		Per Cent
		1932	1933	1934	1935	1936	1937	1938	1939	1940	1932–33	1934-1940	Increase
1	11	27.2	1.14	34.9	16.2	35	13.7	45.2	11.9	44.9	14.17	26.1	84.6
2	21	22.1	.4	25.3	28	26.6	31.4	25.3	32.5	23.1	11.25	28.2	150.

accomplished by lighter thinning. The upward trend in yields subsequent to 1934 is accounted for by the fact that "filler" trees within the orchard were removed in 1933 and that heavier annual applications of nitrogen fertilizer were made thereafter. Trees in Experiment 2, however, after 7 years of remarkably uniform annual cropping appear to be slightly reverting to an alternate bearing habit. The greatest deviation from the "mean average yield" during the years 1934 to 1937 inclusive, was 12.9 per cent and, that for the succeeding biennium, was 20.8 per cent. With Experiment 1, however, maximum deviations during corresponding years, were 44.9 and 64.9 per cent.

DICUSSION AND CONCLUSIONS

The practical results of "bulk thinning" were so distinctly encouraging as to induce another line of investigation now under way at the Hood River Branch Experiment Station. The use of tar oil sprays early in the bloom stage during full bloom to cheaply and effectively remove a major proportion of all fruit from certain limbs on which alternate bearing may be thereby reversed is another and apparently practical means of accomplishing the same result.

The data indicate that early and heavy thinning of alternate bearing Yellow Newtowns during the "on" year has not only induced nearly uniform annual cropping, but also has persisted in effect for several years thereafter. The influence of "bulk blossom" and "bulk calyx" thinning in reversing the alternate bearing habit of individual limbs and the relation of such practices to annual cropping are shown.

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Quality of Deglet Noor Date Fruits as Influenced by Bunch Thinning

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FRUIT thinning of dates has been found necessary (a) to insure adequate flowering the following year; (b) to increase size and improve quality of fruit; and (c) to lighten the bunch and make it less compact and easier to handle. Earlier work (2) has already shown that "moderate" bunch thinning of the Deglet Noor variety according to the current method is, in general, commercially satisfactory, but that "heavy" bunch thinning greatly reduces yield and increases blacknose. However, there has been no evaluation of the physiological factors which might be responsible for the effects of fruit thinning. Investigations of Haller and Magness (1) and of others have emphasized the importance of leaf area in the growth of other fruits and have shown that increased size of fruit following fruit thinning is, in large part, the result of increased leaf area per fruit remaining, which increases the carbohydrate supply.

With dates, the number of fruits can be reduced either by reducing the number of fruits per bunch (bunch thinning) or by reducing the number of bunches (bunch removal). Merely reducing the number of bunches (the only method used in most of the date growing areas of the Old World) is not adequate in producing the size and quality desired in this country, since many observations indicate that even when there are only one or two bunches on a palm, without bunch thinning the fruit is nearly as poor as when all bunches are left. Furthermore, on any one bunch the number of fruits on one strand as well as the location of the strand within the bunch have appeared to affect the size and quality of fruit. Therefore in studying the responses to thinning it has been desirable to consider both the effect of method of bunch thinning and the effect of amount of leaf area per bunch. Only the effects of the methods of bunch thinning will be reported in this paper.

Because of its commercial importance, the Deglet Noor variety was used. Other varieties, particularly the softer dates, appear from preliminary studies to respond somewhat differently to the different methods of bunch thinning, and results with them will be reported when more complete data are available. Methods of bunch thinning were compared by applying different treatments to comparable bunches on the same palm. All thinning was done within 2 or 3 weeks after pollination. As the set of date fruits is not apparent until 5 or 6 weeks after pollination, thinning was proportional to the total number of flowers.

DIFFERENT AMOUNTS OF BUNCH THINNING

To obtain further information on the effect of amount of bunch thinning upon size and quality of fruit, different amounts of bunch thinning were compared on different bunches on the same palm in 1935. Results obtained by using the commercial method of thinning

TABLE I—EFFECT OF DIFFERENT AMOUNTS OF BUNCH THINNING ON FRESH WEIGHT AND SHRIVEL OF DEGLET NOOR FRUIT (1935)

Percentage of young fruits (and unfertilized flowers) removed*	0	10	30	50	70
Percentage of flowers setting fruit	68	70	55	55	44
Number of fruits per strand	40	31	28	22	10
Number of fruits per bunch—calculated	3310	2518	2494	1306	525
Fresh weight per fruit (grams)	7.0	7.2	7.7	8.6	9.9
Weight of fruit per bunch—calculated (grams)	23170	18130	19204	11232	5198
Weight of 10 seeds (grams)	9.6	9.9	10.6	10.4	10.0
Percentage of fruit prematurely shriveled	30.5	21.6	9.5	3.5	0

*Treatments on different bunches on the same palm. Data represent average of four replications, each on a different palm, for 0, 10 and 50 per cent reductions and three similar replications for 30 and 70 per cent reductions. In the 10 and 30 per cent reductions only the tips of strands were cut; in the larger reductions some entire strands were cut from the center of the bunch; 100 fruits in sample from each bunch.

(cutting back tips of all strands and removing entirely some center strands) are summarized in Table I. Although bunches of apparently the same size were chosen for the different treatments, those used for the 30 per cent thinning proved to be slightly larger than the others. This accounts for the slightly greater weight of fruit per bunch with 30 per cent thinning as compared with 10 per cent thinning. Nevertheless, the 30 per cent thinning produced larger individual fruits than the 10 per cent thinning. The smaller percentage set on the bunches given the heavier thinning treatments appeared to be due to the removal of more of the distal end of the strand, which had the higher set of fruit. Typical bunches of fruit, with different degrees of bunch thinning, as they appeared at the beginning of ripening are shown in Fig. 1. It is apparent that reducing the number of fruits per bunch resulted in larger individual fruits, but reduced the total yield per bunch.

A reduction of 50 per cent, compared with no thinning, increased fresh weight from 7.0 to 8.6 grams per fruit, an increase of 23 per cent. Seventy per cent thinning increased fresh weight per fruit 41 per

FIG. 1. Typical bunches of Deglet Noor dates resulting from different amounts of bunch thinning. A, no thinning; B, 50 per cent thinning; C, 70 per cent thinning.

cent. These results are more or less comparable to those obtained with entire palms the previous year (2), when a 56 per cent reduction in number of fruits per bunch resulted in a 26 per cent increase in fresh weight per fruit. Commercially a fruit weighing 7 grams is too small to meet present size standards, while a fruit weighing 8.6 grams is just large enough to come within the minimum size standard.

Shrivel on an unthinned bunch occurs mostly near the tips of the strands Fig. 1, A). This shrivel is probably the result of an insufficient supply of water and carbohydrates, but it is entirely possible that there is a limitation of some other substance. The percentage of fruit prematurely shriveled was reduced as the amount of thinning was increased. This reduction may have been the result of removing a large proportion of the distal end of the strands, or of reducing the number of fruits per bunch drawing upon the available supply of water and carbohydrates.

DIFFERENT METHODS OF BUNCH THINNING

The results of seven different methods of bunch thinning, covering experiments carried out from 1935 to 1939, are included in Table II. These methods involve the removal of strands from different parts of the bunch (Fig. 2), or the removal of flowers or fruits in different ways or from different parts of the strand, or a combination of both. As differ-

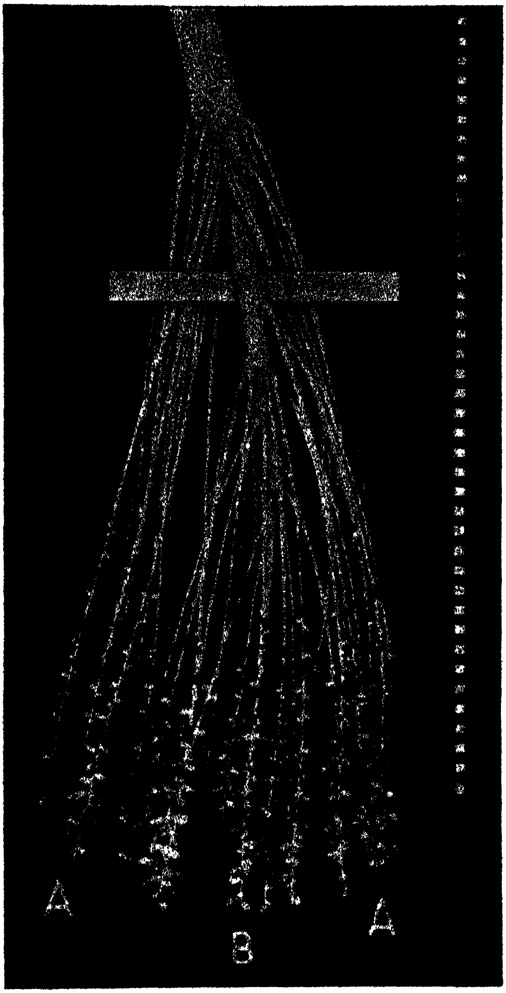

FIG. 2. A bunch of Deglet Noor date fruits early in the growing season showing positions of (A) outside strands and (B) inside strands. About one-third of the flowers were removed by cutting back tips of all strands at time of pollination. Above the strands is the fruit stalk which connects the bunch with the trunk of the palm. Scale units in centimeters.

TABLE II—FRESH AND DRY WEIGHT PER FRUIT OF DEGLET NOOR DATES PRODUCED BY DIFFERENT METHODS OF BUNCH THINNING*

Recorded Data	Year				
	1935	1936	1937	1939	1939†
Percentage of young fruits (and unfertilized flowers) removed	50	75	65	50	50
Number of replications	4	4	8	9	**
Number of fruits in sample from each bunch	100	200	50	100	8
	Weight per Fruit (Grams)				
Fruit thinned by removing:	Fresh				Dry
A Tips of all strands	9.3	14.0	—	8.8	6.1
B All tips and some entire strands from center	8.9	13.6	10.9	—	—
C Entire strands from center	8.7	13.1	10.4	8.4	5.6
D Entire strands from outside	7.7	12.3	9.1	7.8	5.3
E Strands distributed through bunch	8.5	12.8	9.8	—	—
F No thinning	6.3	—	—	—	—
G Fruits from distal end	—	—	—	8.9	6.1
H Fruits from proximal end	—	—	—	8.5	5.9

*Different treatments compared on different bunches on the same palm with replications on different palms.

**Data obtained from a composite sample representing all bunches in each treatment; seeds removed.

†Sampling for dry weight determinations given below.

ent palms were used for experiments in different years, fluctuations in fresh weight between years cannot be entirely explained by differences in amount of thinning but must be attributed in part to differences in leaf area, palm vigor, or other factors. However, the relationship between treatments in any single year is fairly consistent.

The highest fresh weight per fruit has been consistently produced on the proximal portion of the strand when the tips were removed, or, as in 1939, when the fruit was removed from the tips of the strands without cutting back. Except for no thinning, the smallest fruits were produced on the center strands when the outside strands were removed. With reference to position of the strands, it is evident that outside strands produced larger fruits than inside strands. That the differences in fresh weight were accompanied by corresponding differences in dry weight (mostly sugar) is indicated by data obtained in 1939 (Table II).

In the data presented in Table II the number of replications in 1935 and 1936 is too small for the significance of the differences to be evaluated by statistical methods. However, analysis of variance applied to the 1937 data shows fresh weight per fruit from treatment B (removing tips, with some entire strands removed from center) to be significantly higher (.05 level) than either treatment D (entire strands removed from outside) or treatment E (removing strands distributed throughout the bunch). The fresh weight per fruit from treatment C (removing entire strands from center) is also significantly higher (.05 level) than that from treatment D. In the 1939 experiments fresh weight per fruit is significantly higher (.05 level) in treatment A (removing tips of all strands) than in either treatment C or D. In addition, the fresh weight per fruit from treatment G (fruits removed from distal end) is significantly higher (.05 level) than fruit from treatment H (fruits removed from proximal end). Treatment D produced very significantly (.01 level) lower fresh weight per fruit than any other treatment.

The large differences in fruit size between thinned and unthinned bunches, in contrast to the relatively small differences between different methods of bunch thinning suggests that the number of fruits per bunch, rather than the number of fruits per strand or the number of strands per bunch, is the dominant factor in limiting fruit size, provided adequate carbohydrates and water are available to the bunch. However, the slightly larger size of fruit when center strands were removed than when outside strands were removed, and the slightly larger fruit when tips were cut back than when entire strands were removed, indicate that some factors other than the number of fruits per bunch are involved. The vascular connections of the outside strands may facilitate more rapid movements of water or carbohydrates to the fruit than the vascular connections of the inside strands. The larger size of fruit produced by cutting back as compared with taking out strands suggests either that the cross-transfer within the fruit stalk of water and carbohydrates between the vascular elements leading to different strands may be limited to some extent, or that some factor within the strand limits the rate of translocation of water or carbohydrates to the fruits.

That cross-transfer of carbohydrates is limited more than cross-transfer of water was indicated by an experiment with the Thoory variety in 1939. A transverse notch cut in the fruit stalk, between the bunch and the trunk, while the fruits were quite small, reduced the amount of growth made by fruits on strands in line with the notch (Table III). Fruit in line with the unnotched side developed normally.

TABLE III—EFFECT OF NOTCHING FRUIT STALKS ON SIZE OF THOORY DATE FRUITS

Recorded Data	Notched Side*	Unnotched Side*	Check Side 1**	Check Side 2**
	June 20†			
Fresh weight per fruit, seed included (grams)	4.57	5.03	4.46	4.48
Fresh weight per fruit, seed excluded (grams)	3.96	4.39	3.93	3.95
Dry weight per fruit seed included (grams)	0.65	0.68	0.63	0.63
Fresh weight per seed (grams)	0.61	0.64	0.53	0.63
	August 29			
Fresh weight per fruit, seed included (grams)	6.03	9.43	9.24	9.22
Fresh weight per fruit, seed excluded (grams)	4.99	8.21	7.99	7.99
Dry weight per fruit, seed excluded (grams)	1.37	3.57	3.21	2.91
Fresh weight per seed (grams)	1.04	1.22	1.25	1.23
Dry weight per seed (grams)	0.66	0.81	0.81	0.78

*Data from composite sample of 112 dates, seven from each of 16 replications, two on each of eight palms.

**Data from composite sample of 56 dates, seven from each of eight replications, one on each of the palms used for notching treatments.

†Ten fruit stalks notched on June 15, six on June 20.

TABLE IV—PERCENTAGE OF SHRIVEL AND BLACKNOSE OF DEGLET NOOR FRUIT WITH DIFFERENT METHODS OF THINNING*

Recorded Data	Shrivel	Blacknose	
	1935	1936	1939
Percentage of young fruit (and unfertilized flowers) removed	50	75	50
Fruit thinned by removing:			
Tips of strands alone	3.7	18.0	10.3
Tips with some entire strands from center	9.7	16.5	—
Entire strands from center	8.7	8.6	2.9
Entire strands from outside	16.0	9.2	2.0
Strands distributed through bunch	11.3	5.9	—
No thinning	40.9	—	—
Fruit from distal end	—	—	8.4
Fruit from proximal end	—	—	5.1

*Treatments compared on different bunches on the same palm with replications on different palms; four in 1935 and 1936, seven in 1939. Data represents the averages for each year.

Since the final fruit sampling showed more difference in dry matter than in water content, it may be inferred that the cross-transfer of carbohydrates from one vascular bundle to another took place less readily than that of water.

Shrivel occurred in sufficient quantity to be a factor in the Deglet Noor experiments only in 1935. The results (Table IV) showed that the treatments which produced the largest fruits seemed to prevent shrivel.

The effect of method of thinning the bunch upon the percentage of fruits affected with blacknose, which was of consequence only in 1936 and 1939, showed (Table IV) in general that the treatments of removing tips, either with or without removing center strands, also resulted in the greatest percentage of blacknose. From these limited data it would seem that the factors responsible for the larger fruits also favored greater blacknose development.

INTERRELATION BETWEEN STRANDS

The effect of differential thinning on strands on the same bunch was studied in a number of experiments. Fresh weight was usually

TABLE V—FRESH WEIGHT OF DEGLET NOOR FRUIT FROM DIFFERENT THINNING TREATMENTS ON DIFFERENT STRANDS ON THE SAME BUNCH

Percentage of Young Fruits (and Unfertilized Flowers) Removed	Number of Fruits Per Strand at Maturity	Average Fresh Weight Per Fruit (Grams)
	*1935**	
0	36	8.2
10	32	8.3
30	25	8.9
50	17	9.4
70	10	9.5
70 (June 1)	11	8.8
	1936†	
0	26	13.0
25	19	13.5
50	12	14.0
75	6	14.0

*Seven replications, 10 fruits in sample from each bunch.
†Four replications. 24 to 142 fruits in sample from each bunch.

increased only 5 to 10 per cent (in one instance 15 per cent, Table V) by reducing the number of fruits per strand 50 per cent, and there was little or no additional increase from thinning beyond 50 per cent. Furthermore, the difference in size between fruit on thinned and on unthinned strands was about the same regardless of what was done to the strands not used. In the experiments included in Table V, the strands not used were all removed. In another experiment with all strands retained, when three-fourths of the strands were thinned 75 per cent the fresh weight per fruit was only 6 per cent greater than that of the fruit on unthinned strands.

The effect of thinning a few strands on a bunch otherwise unthinned was tried in 1938. On one bunch 50 per cent thinning by cutting back tips on three strands gave a fresh weight per fruit of 11.5 grams as compared with 10.8 grams on unthinned strands. On another bunch 50 per cent thinning by removing alternate fruits on two strands gave a fresh weight per fruit of 11.9 grams as compared with 11.0 grams on unthinned strands. However, it was apparent that the fresh weight of fruit on unthinned strands (the lowest fresh weight was 8.2 grams) in all the experiments where other strands on the same bunch were thinned was higher than that on bunches entirely unthinned in previous experiments (in which the highest fresh weight was 7.0 grams).

Such results indicate that: (a) water or carbohydrates not utilized on a thinned strand are to some extent available to unthinned strands on the same bunch; but (b) this cross-transfer in the fruit stalk of water or carbohydrates from the vascular bundles of one strand to the vascular bundles of another strand is not sufficiently great to distribute the carbohydrates equally on thinned and unthinned strands, so that up to a certain point the fewer fruits per strand the larger the size of the fruit. That cross-transfer of water and carbohydrates takes place more readily in the fruit stalk than in the trunk is indicated by the relatively small differences in size of fruit obtained from different thinning treatments on different strands on the same bunch as compared with the much larger differences obtained from comparable treatments on different bunches on the same palm (Table I).

STRAND SIZE

That thick strands may produce somewhat larger fruit than comparable slender strands was indicated by results obtained in 1938. All strands on two bunches were thinned to the same number of fruits per strand and the size of the fruit measured in the khalal[1] stage, before it was affected by shrivel or adverse weather conditions. As an index of strand thickness the maximum and minimum diameters were measured. Fruits from only the thickest and the slenderest strands were compared. The fresh weight per fruit was about 6 per cent higher on the thick strands than on the slender strands on one bunch and about 10 per cent higher on the other bunch. These results indicate that some factor within the strand, presumably the size of vascular tissue, affects the rate of growth of the fruit.

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[1] The stage immediately preceding final softening and ripening; Deglet Noor fruit is a coral red color during this period.

Bunch Size

In 1935 one large and one small inflorescence on each of four different palms were thinned to approximately the same number of flowers. The average number of flowers before thinning was 5,952 for the large inflorescences and 2,810 for the small inflorescences; after thinning there were 2,044 and 2,041 respectively. The resulting average fresh weight per fruit (100 fruits in sample from each bunch) was 12 per cent greater from the large inflorescences (9.2 grams) than from the small inflorescenes (8.2 grams). It is evident that the large inflorescences could have carried satisfactorily a larger number of fruits than the small inflorescences. Although the size of the fruit stalk was not measured in these treatments, a marked difference in the size of the bunch is always accompanied by a difference in the size of the fruit stalk. It would appear, therefore, that the size of the fruit stalk also affects the rate of growth of the fruit.

Summary

Reducing the number of fruits per bunch increased size and generally improved quality of date fruits. Reducing the number of fruits per strand resulted in larger fruits than an equivalent amount of thinning by removing entire strands. Larger fruits were produced on the outside strands when the inside strands were removed than on the inside strands when the outside strands were removed. Reducing the number of fruits on some strands seemed to increase the size of fruits on other strands on the same bunch. In general, methods of bunch thinning which increased the size of fruit tended to reduce the amount of shrivel but increase the susceptibility to blacknose. The results obtained indicate that some cross-transfer of water and carbohydrates occurs in the fruit stalk between vascular bundles leading to the different strands. However, some factor or factors limit either the amount of cross-transfer or the movement through the strands to the extent that water or carbohydrates are not equally available throughout the bunch.

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Initiation of Peach Flower Parts

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A STUDY of the data available on the initiation of flower parts in the fruit buds of the peach led to the conclusion that additional information might be desirable. Auchter and Knapp (1) state that most investigators find differentiation beginning in July, but Michigan (3) and Wisconsin (4) report differentiation in September. The work of Barnard and Read, cited by Dorsey (3), indicates fruit bud formation in Australia in late January, which tends to confirm the statement of Auchter and Knapp, since January in the southern hemisphere corresponds to July in the northern hemisphere. Gourley's review (5) does not further clarify the matter. Chandler (2) mentions some differences in the behavior of varieties. Such differences might be expected in view of the heterozygosity of the peach but the immediate factors determining the time of differentiation are not fully determined. Recent work on the effect of length of day and temperature on the initiation of floral structures in other plants seems to offer an inviting lead. Although most of the work so far done has been with annual plants there seems no reason to believe that length of day could not be operative in flower part initiation of perennial woody plants as well.

Before it was possible to start any work leading toward a trial of the idea that length of day is in any way connected with flower initiation in the peach it was necessary to determine when the process began at Iowa Park. A beginning was made in 1940 with a study of a single variety, Dr. Burton, for the sake of making a careful examination to determine the course of flower initiation. Enough buds were sectioned on each sampling date to leave no doubt that development beyond the most advanced state observed had not taken place.

Sections made at weekly intervals beginning the middle of June showed no sign of floral initiation until August 10.

In 1941 a much more extensive program was carried out. Mayflower, Early Rose Cling, Dr. Burton, Frank, Dee Lee Cling, Smith (a Honey peach), and "Late", an unknown variety maturing between September 6 and 13 were studied. The first collection was made July 27 and the second August 4. At neither date was there any sign of flower initiation in any variety. The next collection was made August 15. At this time flower parts were well advanced in Early Rose Cling with corolla and stamens well formed. An initial stage was observed in the variety Dr. Burton. The next collection was made on August 24 by which time the most advanced buds of Dr. Burton were showing all flower parts. The other varieties showed no sign of flower initiation until September 3 when Frank showed a typical primary stage. On the last collection, September 13, the varieties Dee Lee Cling, Mayflower and "Late" showed all flower parts in a much less advanced stage than did Frank, Early Rose Cling, and Dr. Burton, all of which had well developed anthers and pistils at this date. A summary of the results is given in Table I.

The summary table shows that there is no connection between the

TABLE I—SUMMARY OF RESULTS

Variety	Date Fruit Ripens	Date Floral Parts First Identified	Tentative Date of Initiation	Length of Day*	
				Hrs	Min
Mayflower	Jun 4	Sep 13	Sep 8	12	37
Early Rose Cling	Jun 15	Aug 15	Aug 10	13	31
Dr. Burton	Jul 1	Aug 10	Aug 10	13	31
Frank	Aug 20	Sep 3	Sep 3	13	3
Dee Lee Cling	Aug 20	Sep 13	Sep 6	12	41
"Late"	Sep 10	Sep 13	Sep 8	12	37
Smith (Honey)	Aug 15	Sep 13	Sep 13	12	28

*Data for 32° 30′ north; latitude of station is 33° 55′ north.

time of fruit maturity and flower initiation. Mayflower is one of the earliest maturing varieties, yet one of the latest to initiate flowers. Incidentally it is a mid-season bloomer and blooms before Dr. Burton. The data on length of day is included merely to show the length of day at which flower initiation was believed to occur. It is not proof that length of day is involved in peach flower initiation. Early Rose Cling and Dr. Burton developed flowers earlier, and consequently when days were longer, than did the other peaches observed.

In order to test whether length of day is casually related to the time of flower formation or more directly so it is planned to conduct a series of observations under artificially controlled light periods.

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Investigations on the Time of Blossom Induction in Wealthy Apple Trees[1]

By B. ESTHER STRUCKMEYER and R. H. ROBERTS, *University of Wisconsin, Madison, Wis.*

CONSIDERABLE emphasis has recently been placed on the floral induction of plants. Induction as here used refers to the internal changes taking place during the transformation of plants from a vegetative to a flowering condition, occurring before the appearance of blossom primordia. Previous investigations have shown that structural changes in annuals occur within the plant prior to the formation of blossom buds (6). Since it has been shown that the formation of blossom buds is largely dependent on the area of the leaves, "defoliation" was the method used to determine, if possible, when induction occurs (5). Defoliation, as here used, means a reduction in leaf area by the removal of 85.0 per cent of the leaf blades. Wealthy was chosen because of the almost complete absence of blossom buds at growing points one year and the almost 100 per cent presence of blossom buds in the alternate year.

Potter, Kraybill, and Wentworth (5) reported that when all blossoms were removed from Oldenburg apple trees, 41.1 per cent of the spurs produced blossoms the following season. If the blossoms from alternate spurs were removed (50.0 per cent) blossom buds were formed on only 10.0 per cent of the deflorated spurs. Bowman (2) observed that the removal of blossoms from all spurs, except every 6th one, enabled the deflorated spurs to again produce blossom buds in successive years. Bobb and Blake (1) and Fischer and Britton (4) also observed that defloration was a means of producing an increased number of repeat blossom buds on on-year trees.

Christoph (3) showed that the anatomical structure of on-year and off-year spurs was different.

METHODS

Branches of fruiting or "on-year" trees were deflorated to observe the extent to which the removal of the blossoms would result in the formation of blossom buds for the second consecutive year. The leaf area of spurs on trees in a vegetative condition, or "off-year" spurs, was reduced to determine whether the removal of a major portion of the leaf blades would inhibit the formation of blossom buds. Since Wealthy trees blossom and differentiate blossom buds on different calendar dates from year to year, these dates could not be used in averaging the results for the years 1940 and 1941. Instead, treatments made the same number of days before or after the full bloom stage for the two years were compared and the results averaged. Branches with approximately 200 spurs each were used. Four branches on on-year trees were deflorated every third or fourth day beginning at the green tip stage and continuing until 2 weeks after full bloom. Four branches were defoliated at intervals of 3 or 4 days on "off-year" trees from the time of full bloom until blossom primordia were present.

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[1] Published with the permission of the Director of the Agricultural Experiment Station.

In 1940 only the two terminal leaves of each spur from several branches were defoliated. In 1941 the area of all leaves on the spurs of some branches, except the two teminal ones, were reduced. Later all the leaves from early deflorated spurs on some branches were defoliated. In September and October of 1940 and 1941, the majority of buds were collected and sectioned to determine the percentage of blossom buds formed. The type of buds remaining on the trees was determined at blossom time in the spring of 1941 for the treatments made in 1940. The area of the two terminal leaves of spurs deflorated and defoliated was measured.

Samples of the new growth of on-year and off-year spurs were taken from the time of full bloom until blossom primordia were observed to determine when any anatomical differences became evident. The samples were fixed in formalin-acetic-alcohol, dehydrated by the cedarwood oil method and embedded in paraffin. The sections were cut on a rotary microtome, 15 microns in thickness and stained with safranin and Delafield's haematoxylin.

Cross-sections of on-year and off-year spurs were passed through a micro-incinerator to disclose the mineral pattern. Cross-sections of leaves from on-year and off-year spurs were examined.

RESULTS

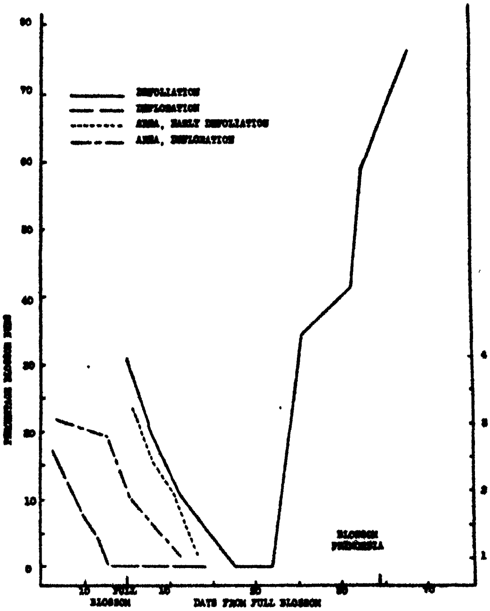

FIG. 1. Percentage of blossom buds on deflorated and defoliated spurs with the corresponding average area of the two terminal leaves from these spurs.

The average number of blossom buds formed and the average area of the two terminal leaves for 1940 and 1941 deflorated and defoliated spurs was determined. Blossom buds were formed only on spurs deflorated before the time of full bloom. Defloration gradually became less effective in producing blossom buds as the time of full bloom approached. Spurs deflorated 17 days prior to full bloom produced 17.0 per cent repeat blossom buds; spurs deflorated 10 days before full bloom formed 7.5 per cent repeat blossom buds; and spurs deflorated 5 days before full bloom produced only vegetative buds (Fig. 1).

By comparing the leaf

area with the percentage of blossom buds formed, one can understand why blossom buds were again produced on some of the earlier deflorated spurs (Fig. 2). The average area of the two terminal leaves on spurs deflorated 17 days before full bloom (which was also the time the greatest number of blossom buds were formed) was 3 square inches. Five days before full bloom, when no blossom buds were formed, the leaf area of deflorated spurs was 2.3 square inches. On spurs which were deflorated 12 days after full bloom, the leaf area was 1.0 square inch. From these results it appears that the successive formation of blossom buds is dependent upon the area of the leaves.

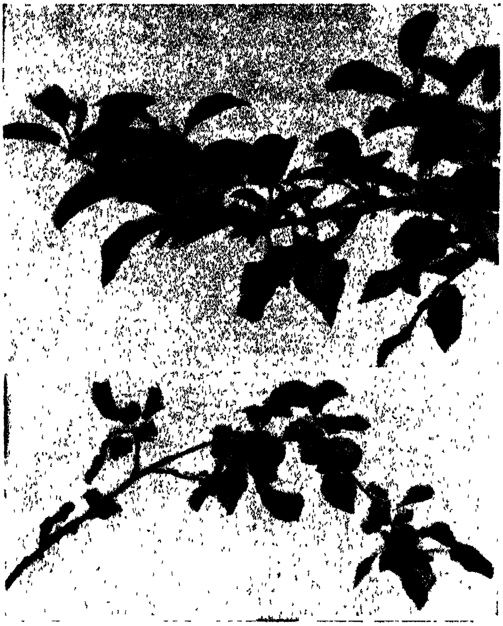

FIG. 2. Upper: Typical foliage on branch deflorated in the green tip stage. Lower: Typical foliage on branch of an on-year or fruiting tree.

When spurs which had been deflorated sufficiently early to again produce blossom buds were defoliated 2 weeks after full bloom, the formation of blossom buds was inhibited.

Those spurs defoliated at the time of full bloom produced about 22.0 per cent blossom buds. After this defoliation treatment, new growth occurred and the average leaf area of the two terminal leaves was 4.0 square inches. On the spurs defoliated, 16 days following full bloom all buds were vegetative and the average leaf area of the two terminal leaves was 1.0 square inch.

Blossom buds were not formed on spurs defoliated in the interval of 16 to 34 days after full bloom. Spurs did not produce new leaves beyond 16 days after full bloom. When reduction of leaf area was deferred to 40 days after full bloom, 34.0 per cent of the spurs formed blossom buds (Fig. 1). Spurs defoliated beyond 40 days produced an increasingly greater percentage of blossom buds.

Blossom primordia were first apparent 59 days after full bloom in both years. These data show that induction could have occurred 3 weeks after full bloom and at least 3 weeks before the appearance of blossom primordia.

In 1940 spurs on which the two-tip leaves were defoliated shortly after full bloom failed to produce blossom buds. In 1941 the earliest tip defoliated spurs produced about 15.0 per cent blossom buds. Defoliation of the two terminal leaves had less effect on inhibiting blossom formation than did defoliation of all the leaves since 42 days after full bloom spurs with only the terminal leaves defoliated produced almost 100 per cent blossom buds and those spurs with all leaves defoliated produced 34.0 per cent blossom buds. Defoliating all the leaves on the spurs, except the two terminal ones, had approximately the same effect as defoliation of the two terminal leaves. These results further reveal

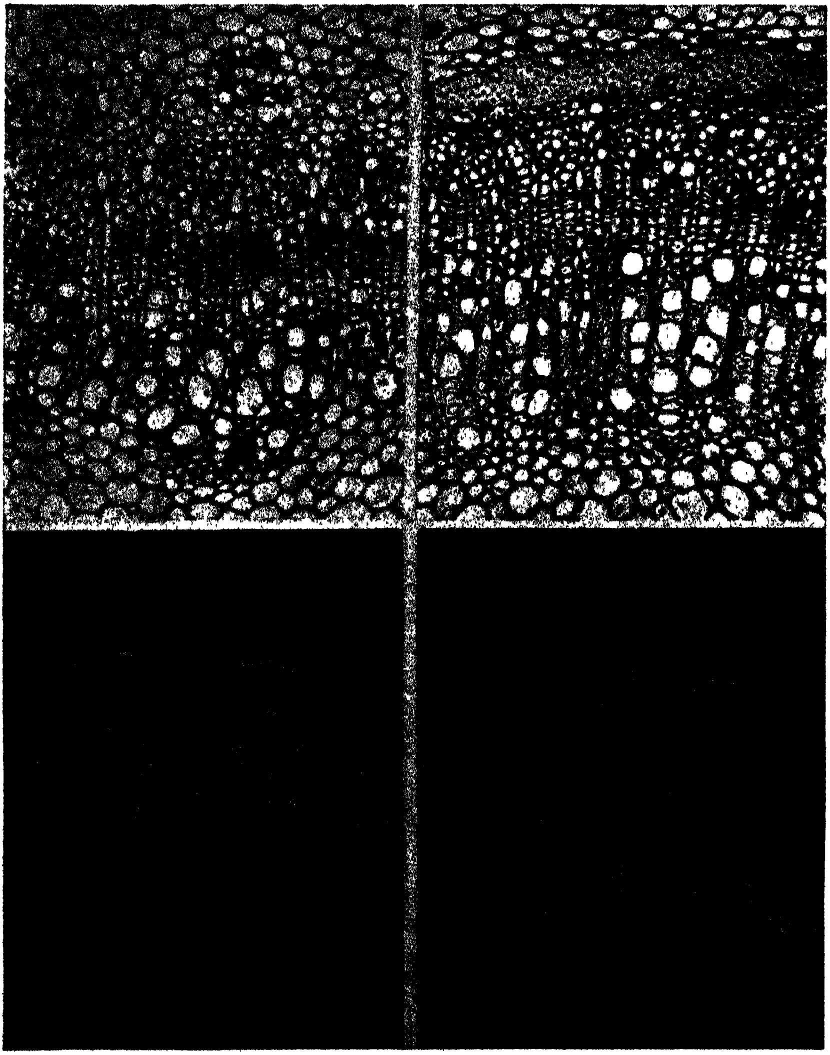

Fig. 3. Upper left: Cross-section of stem from on-year spur. Upper right: Cross-section of stem from off-year spur. Lower left: Mineral residue in cross-section from on-year spur. Lower right: Mineral residue in cross-section from off-year spur.

the importance of leaves in the formation of blossom buds.

Christoph (3) in 1939 showed that differences existed in the anatomical structure of on-year and off-year spurs of Wealthy prior to the formation of blossom primordia. Samples for the examination of the anatomical condition were again taken in 1940 and 1941 and the results were found to agree with the observations made by Christoph. There is a difference in the type of cambium present, being less active in the off-year spur. In the phloem region of the off-year spur a greater number of parenchyma cells are present and the walls of these cells are thicker. Thicker-walled ray cells are present in the off-year stem (Fig. 3).

A difference in the mineral pattern between off-year and on-year spurs was apparent (Fig. 3). These differences in the anatomical structure and the mineral pattern became apparent about 4 weeks after full bloom and 4 to 5 weeks before blossom primordia were apparent.

Cross-sections of leaves from on-year and off-year spurs revealed that the leaves from off-year spurs were thicker and the number of palisade cells was greater (Fig. 4).

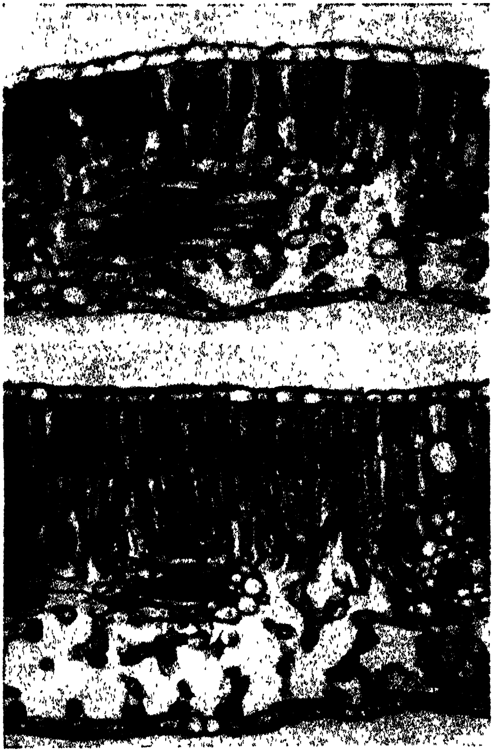

FIG. 4. Upper: Cross-section of leaf from on-year spur. Lower: Cross-section of leaf from off-year spur.

DISCUSSION

It is generally assumed that the appearance of blossom primordia marks the beginning of the reproductive state in higher plants. Observations from anatomical investigations have shown that induction occurs considerably before the presence of blossom primordia in some species. With regard to Wealthy, it is apparent that this variety has progressed far enough toward blossoming 3 to 4 weeks prior to the appearance of primordia that reduction in leaf area does not inhibit bud formation.

The repeated formation of blossom buds on spurs deflorated before full bloom is the result of increase in leaf area after defloration and not defloration itself. The failure of early defoliation to inhibit formation of blossom primordia is a parallel case since the production of new leaves may lead to blossom initiation.

Defoliation experiments indicated that induction occurred at least 3 weeks previous to the appearance of blossom primordia. This is shown by the fact that spurs defoliated 3 weeks before the appearance of blossom primordia did not produce new leaves but formed blossom buds indicating that blossom induction had occurred before the leaves were removed. Since primordia were first apparent 59 days after the time of full bloom and since defoliation 40 days after full bloom no longer inhibited blossom bud formation, induction must have occurred at least 3 weeks prior to the appearance of blossom primordia.

The present studies do not show definitely when induction started. Three weeks after full bloom the new leaves on early defoliated and deflorated spurs would have reached their maximum size and induction could have occurred this early. Further evidence that it may have occurred at this time is the fact that differences in the anatomical structure and mineral pattern were apparent at least 4 weeks after full bloom.

Since it has been shown that leaves are essential for blossom bud formation during the period of 2 to 6 weeks after full bloom, sprays should be carefully applied during the induction period so as to prevent spray injury to the leaves. These investigations also suggest the importance of making observations at or before the induction period when attempting to study the nature of blossom initiation in plants.

SUMMARY

The blossoms from on-year trees of Wealthy and 85.0 per cent of the leaf area from off-year trees was removed to secure evidence on the time of blossom bud induction. If the blossoms were removed before full bloom, larger leaves were produced and some blossom buds were differentiated.

The reduction in leaf area on early deflorated spurs inhibited the formation of blossom buds. Spurs defoliated at the time of full bloom and 2 weeks thereafter produced new leaves and some blossom buds. Spurs defoliated 3 weeks after full bloom did not form new leaves and the buds formed were vegetative. Spurs defoliated 5 weeks after full bloom formed a number of blossom buds. Induction had progressed to the extent that total leaf area was no longer essential to the formation of blossom buds.

Differences in the anatomical structure of the spurs from off-year and on-year trees were apparent about 4 weeks after full bloom and 9 to 10 days before defoliation failed to completely inhibit blossom formation. These changes became apparent during the induction period.

The mineral pattern of incinerated sections of off-year and on-year spurs was unlike. The localization of the mineral residue was different in the two types of spurs.

Reducing the area of the two-tip leaves shortly after full bloom was effective in inhibiting blossom bud formation. It was less effective than defoliation of all the leaves of the spurs. Since the leaves are important in blossom bud formation, spraying operations should be carefully planned to prevent injury to the leaves during the induction period.

When studying blossoming it might be well to begin sampling at the induction period instead of after blossom primordia are apparent.

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Russeting of Golden Delicious Apples

By F. B. CHANDLER and I. C. MASON, *Maine Agricultural Experiment Station, Orono, Me.*

RUSSETING of Golden Delicious apples has been observed and studied for some time. Plant pathologists have reported the effect of sprays on the russeting of other varieties of apples. Drain (2) and Gardner, Bradford, and Hooker (5) have reported a difference in russeting in different localities. The latter authors have also stated that russeting appears more pronounced during seasons or in sections of high atmospheric humidity. Folsom (3 and 4) in 1933 and 1934, working in the Golden Delicious orchard where the experiments to be described were conducted, found as much russeting on unsprayed trees as on sprayed trees. Many other investigators have realized that russeting might also be caused by factors other than spraying. This paper is a report on some of these factors.

METHODS

Golden Delicious trees were set in 1925 in an orchard 35 miles from the coast. The trees have been sprayed with lime sulphur, mild lime sulphur and calcium arsenate with lime. Copper has never been used in the spray on these trees. In 1935 the percentage of russeting of the apples on 25 different trees was found to vary from 30.6 to 100 (an apple was called russeted if 5 per cent of the surface outside of the stem cavity was russeted). In 1936 scions from the "low russet fruit" trees (below 50 per cent mean 38.6 per cent) were grafted onto both "high russet fruit" trees (above 90 per cent mean 95.6 per cent) and "low russet fruit" trees. Reciprocal grafts were also made. In addition to these studies nutrients were added to some trees. In June 1936 trees were injected with 2½ gallons of a complete nutrient solution. In June 1937 boron was applied to a number of trees, as one of the authors had found that a deficiency of this element in some plants of the genus *Brassica* resulted in a cork-like formation (1). In some cases the trees were injected with glycerol-boroglyceride (4.25 or 7.00 cubic centimeters) while other trees received borax as a spray (2 gallons) on the foliage or received ½ pound of borax applied to the soil. Six trees were used for all of the nutrition or boron studies but due to the biennial bearing habit of Golden Delicious only three could be used in the analysis of the data.

RESULTS

The scions have produced some fruit but not enough for statistical analysis of the data. However, there are interesting trends, Table I. When scions from "high russet fruit" trees were grafted onto "low russet fruit" trees, in four out of five cases the fruit from these scions showed a higher percentage of russeting than that from the trees on which they were grafted. In the reciprocal case ("low russet fruit" trees grafted onto "high russet fruit" trees) three times out of four a lower percentage of russeted fruit was obtained from the grafts than from the remainder of the tree. Thus seven out of nine times the results

TABLE I—PERCENTAGE OF RUSSETING OF GOLDEN DELICIOUS FRUITS : HIGH AND LOW RUSSETING SELECTIONS GRAFTED ON TREES PRODUCING LOW AND HIGH RUSSETING FRUIT

Russeting		Difference	Russeting		Difference
Tree (Per Cent)	Graft (Per Cent)		Tree From Which Graft Was Selected (Per Cent)	Graft in New Tree (Per Cent)	
High Russeting Scions on Low Russeting Trees					
8.30	50.00	+41.70	——	——	——
73.87	100.00	+26.13	——	——	——
34.44	46.70	+12.26	55.00	46.70	− 8.30
38.00	20.00	−18.00	55.00	20.00	−35.00
38.00	50.00	+12.00	84.70	50.00	−34.70
——	——	——	83.78	5.56	−78.22
Low Russeting Scions on High Russeting Trees					
83.78	40.00	−43.78	3.66	40.00	+36.34
83.78	60.00	−23.78	73.87	60.00	−13.87
83.78	49.02	−34.76	73.87	49.02	−24.85
98.22	100.00	+ 1.78	51.12	100.00	+48.88

indicate the scion carried a factor, possibly a bad mutation, causing russeting of the fruit. The importance of environmental factors (soil, rootstock and interstock) in causing russeting is shown by similar analysis of the data. In six out of eight observations the percentage of russeted fruit on the scions was found to be influenced by its new environment.

Boron was only applied to "high russet fruit" trees and when the percentages of russeting for the boron treatments are compared by years it is evident that boron did not change the amount of russeting, Table II. There is a significant difference between the different years that this study was made. It is interesting to note that in years of high russeting (1937 and 1940) there are only two significant differences

TABLE II—PERCENTAGE OF RUSSETING OF GOLDEN DELICIOUS APPLES BY YEARS AND TREATMENTS WITH THE DIFFERENCE NECESSARY FOR SIGNIFICANCE

Treatment (Per Tree)	Boron Per Tree (Grams)	Russeting			
		Years			
		1937 (Per Cent)	1938 (Per Cent)	1939 (Per Cent)	1940 (Per Cent)
		Difference necessary for significance 14.88			
Untreated check	0.00	99.5	54.0	28.4	81.7
2½ gallons nutrients (injected)	.00+	95.9	49.3	46.2	91.0
4.25 cubic centimeters glycerol-boroglyceride (injected)	.28	100.0	59.3	68.7	99.0
7.00 cubic centimeters glycerol-boroglyceride (injected)	.38	99.0	70.9	85.8	97.1
2 gallons borax spray (foliage)	1.66	97.0	61.1	62.6	96.0
2 gallons borax spray (foliage)	2.52	95.3	63.3	59.8	83.8
½ pound borax (soil)	25.73	97.9	73.5	82.2	95.8
		Difference necessary for significance 5.62			
Mean for years		96.9	61.6	62.0	92.1

between treatments while in the years when there was a small amount of russeting (1938 and 1939) there are more significant differences between treatments. This indicates that in some years climatic or other factors cause a high percentage of russeting on all trees while in other years bud mutation, interstock, rootstock, and/or soil are more important than climate. Russeting is usually evident by the middle of July yet there was no association between russeting and temperature based on 7-day means from June 3 to July 28. Unfortunately humidity data is not available. During this same period it was impossible to ascribe any significance to precipitation data. The mean weekly precipitation for this period for the years 1935 to 1941 varied from 0.56 to 1.18 but these were not significantly different and were both in years of low russeting. In the two years (1937 and 1941) of abundant russeting no weekly precipitation exceeded 1.58 inches while in the four years (1935, 1938, 1939, and 1941) of little russeting the precipitation exceeded 2 inches in six different weeks of 32.

From these studies it appears that russeting of Golden Delicious apples probably is sometimes caused by one or more of the following: (a) bud mutation, (b) one or more of the factors interstock, rootstock, and soil, and (c) a range of weekly precipitation with a maximum not in excess of 2 inches during the period of June 3 to July 28.

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The Response of Peaches in Kentucky to Cultivation and Cover Crops and to Sod Cultures[1]

By A. J. OLNEY and W. D. ARMSTRONG, *University of Kentucky, Lexington, Ky.*

A BLOCK of Elberta peaches planted at the Western Kentucky Experiment Substation at Princeton, Kentucky, in 1928 and 1929, was divided into plots to study the effect of cover crops, cultivation practices, and fertilizer treatments. The soil was fairly fertile, well-drained clay loam located in the transition zone between limestone and sandstone soils, typical in this section.

This discussion is concerned with the long-time result obtained on certain cultivated plots in comparison with certain sod plots. Because of the lack of replications and the similar results obtained with winter oats, winter barley, and rye as winter cover crops on cultivated plots, and the uniformity of results on certain sod plots, several plots were grouped together for this study:

Group 1. Clean cultivation with winter cover crops, annual nitrogen and manure treatments, gentle slope.

Group 2. Clean cultivation with winter cover crops, annual nitrogen treatment, level land.

Group 3. Same as group 2, except land slopes and erosion was quite severe.

Group 4. Same as group 2, except no cover crops were grown.

Group 5. Same as group 2, except that no fertilizers were used.

Group 6. Seeded to lespedeza in 1933 to prevent erosion. Annual spring cultivation after which lespedeza was allowed to reseed itself. Annual nitrogen treatment.

Group 7. Seeded to sericea lespedeza, a perennial, in 1933. Level soil, nitrated annually.

Group 8. Sloping land, continuously in a combination of sweet clover, lespedeza, redtop, and bluegrass after the first year. Nitrated annually.

Group 9. One year younger than all above. First two years in sweet clover, then seeded to Korean lespedeza, cultivated in 1934 and reseeded to Korean lespedeza in 1935. Nitrated annually. These plots were nearly level and occupied the highest and thinnest ground in the orchard.

Group 10. Similar in all respects to group 9, except that no fertilizers were used.

The plots were rectangular or square; 12 trees in most plots and 9 in the others. There were seven crop failures due to winter damage or spring frosts, and the data are based on the four crops in 1931, 1935, 1937, and 1941. Of these, the 1937 and 1941 crops were considered full crops on mature trees.

Table I presents the production in bushels computed on the basis of a plot of 12 trees.

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[1] The investigation in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

TABLE I—O'HARA PEACH PLOTS (PRINCETON, KENTUCKY)*

Group	Plots No.	Soil Treatment	1931	1935	1937	1941	Total	1941 Bushels Over 2 Inches
1	16	Manure; clean culture +N and cover crop	26	21	104	126	277	108
2	1, 2, 3, 4, 6, 10	Clean culture + clover crop + level land	24	64	91	89	268	70
3	7, 11, 17	Clean culture, cover crop +N, eroded plots	19	56	78	74	227	38
4	13	Clean culture +N level, no cover crop	13	32	88	74	207	12
5	5	Clean culture, cover crop, no N level	19	39	72	38	168	32
6	8, 9	One cultivation followed by lespedeza +N	17	51	102	88	258	47
7	24, 25	Sericea lespedeza sod +N	22	21	69	98	210	83
8	12, 14, 15	Sweet clover and bluegrass, lespedeza sod +N	4	14	63	70	151	40
9	18, 19, 21, 22, 23	Korean lespedeza sod, +N	1	6	49	79	135	50
10	20	Korean lespedeza sod, no N	0	3	28	71	102	55

*Yields grouped by years and plots of similar treatment; represent bushels per 12-tree plot.

In the clean-cultivated groups it will be noted that the yield in group 1 was slightly higher than in group 2. Also, group 1 was the only group in which the yield in 1941 was higher than in 1937. These were followed by lighter yields in group 3, which suffered from erosion, then group 4 with no cover crop, and the unfertilized group 5, last. The decreases in the 1941 yield corresponded to lack of vigor of the trees in the cultivated plots, which was very evident in the appearance of the foliage.

In plots with sod cover crops, group 6 ranked highest, and 3rd highest of all the groups. Group 7, in sericea lespedeza, next, followed by group 8 in combination sod, and the permanent Korean lespedeza groups the lowest of all. It should be noted, however, that the trees in groups 9 and 10 were 1 year younger and that the soil in these plots was less fertile than in any of the other plots, and were in sod almost continuously from the beginning. All other groups except group 8 had several years of cultivation in the early years of the planting.

With respect to maintenance of vigor, group 6 was the only sod treatment to show a decrease in 1941, compared with 1937. The smallest 1941 increase in yield was in the combination sod plots in group 8. The largest increase was in group 10, Korean lespedeza, which received no fertilizer.

These comparisons indicate that the vigor of the trees was maintained better in the sodded than in the cultivated areas. The foliage of the trees in lespedeza sod was much darker green throughout the season than that of the trees in any of the cultivated plots except group 1, and one plot in group 2 which probably was on the best soil. Comparing the two unfertilized groups, 5 and 10, yields and tree vigor declined under cultivation practices but were maintained in sod culture.

The size of the fruit in the 1941 crop was recorded in bushels of fruit 2 inches or more in diameter. The highest percentage of large peaches was from the sericea lespedeza plots, group 7, and this group was also second in the number of bushels of large fruit. Group 1 led in the production of bushels of large fruit, and group 2 was third.

Aside from these, the other sod groups produced a greater per cent of large fruit than the remaining cultivated groups. Also, the fruit from the sod plots had better color and higher finish.

These size comparisons are especially noteworthy, since 1941 was the driest season on record in Western Kentucky. Although the crop was heavily hand-thinned, the size of the fruit was reduced materially by the drought.

Erosion occurred on all cultivated plots and the severity increased as the slope of the land increased. In group 1, the amount of erosion was apparently as great as on other cultivated plots with similar slopes, but the manure seemed to more than offset the loss in fertility.

Because of the dry weather that frequently occurs in Kentucky during September and October, the winter cover crops usually make slow growth and fail to provide adequate protection to the soil during the winter.

The sod plots suffered practically no erosion in spite of the fact that the annual lespedezas died down each fall.

SUMMARY

Cultivation and cover crops resulted in larger trees and larger crops of peaches during the early years of the orchard. On level land not subject to erosion, the cultivation and cover crop systems were most satisfactory during the period covered in this report. On gently sloping land, peach trees under sod culture maintained or improved their vigor and productiveness as the trees became older, while under cultivation there was erosion, and the trees showed a progressive decline in growth and yield.

The Effect of Deflorating or Defruiting Upon Blossom Bud Differentiation in the Sugar Prune

By L. D. Davis, *University of California, Davis, Calif.*

Abstract

This material will be published in full in *Hilgardia.*

THE Sugar prune at Davis, California alternates completely. In its bearing year a very heavy crop will be produced; in the following year many trees will not have even a single blossom on them. The variety is, therefore, very suitable material for studying blossom bud differentiation.

Investigations on deflorating or defruiting have been conducted from 1933 through 1940 to determine (a) the portion of the Sugar prune tree which could be caused to differentiate fruit buds by defloration; (b) the number of seasons over which a unit of the tree, which had been caused to bear out of phase with the tree by deflorating, could maintain its independence of bearing; and (c) the time during which fruit buds could be caused to differentiate by deflorating or defruiting.

From 1933 through 1937 unringed branches of about eight different sizes were deflorated just as the trees were approaching full bloom. The sizes were as follows: individual spurs, approximately 2 inches long; small branches about ¼ inch in diameter and about 1 foot long; branches about ½ inch in diameter and 2½ feet long; branches about ¾ to 1 inch in diameter; those about 1½ to 2 inches in diameter which comprise approximately 3 per cent of the tree; and still larger branches, comprising about 15, 25, and 50 per cent of the tree respectively. Neither of the two smallest groups formed fruit buds after being deflorated; among the groups with larger sizes the following percentages of branches formed fruit buds: ½-inch 15 per cent; ¾- to 1-inch 35 per cent; 1½- to 2-inch 90 per cent; and all larger sizes 100 per cent. When branches of the ½-inch size were ringed and deflorated fruit buds were differentiated on 75 per cent of them as compared to 15 per cent when unringed. The 1½- to 2-inch sized branch, comprising about 3 per cent of the bearing area of the tree, would thus seem to be the smallest unit of the tree that can be caused to form fruit buds with certainty when deflorated but not ringed.

In each of the three years, 1938 through 1940, two trees had all the flowers removed either above or below an imaginary horizontal plane passing through a point that was estimated to divide the tree into two equal parts. In each of the years the deflorated half formed fruit buds in the summer following defloration and bloomed the following spring. None of the untreated halves differentiated fruit buds in the summer following the treatment of the other half.

The ability of a deflorated unit of a Sugar prune tree to differentiate fruit buds and bear fruit out of phase with the remainder of the tree does not necessarily mean that these units can continue to do so. None of the branches in the ½-inch and ¾-inch size have borne out of phase with the tree longer than one year. Branches of these sizes have borne a crop in the year following defloration when they were out of phase with the tree and a crop in the succeeding year when they were in phase with the tree, after which they have borne only in alternate years with the tree. In the 1½- to 2-inch size the branches have not behaved uniformly with respect to bearing in years subsequent to defloration. Some of them have remained out of phase with the tree but one year. These have borne a crop two years in succession and then have borne in the same year as the rest of the tree. Others have been out of phase with the tree 4 or 5 years and then have borne a crop in the same years as the tree. Some of this latter group have come to bear in phase with the tree by bearing two years in succession; others by being non-bearing for two successive years. A few other branches in the 1½- to 2-inch group have continued to bear out of phase with the tree during the period of the investigation. The behavior of this sized branch has been taken to indicate that it is near the minimum size which can be caused to perform and maintain its performance independently of the tree. Branches that comprise about 15, 25, or 50 per cent of the tree have borne out of phase with it for the extent of the investigation. In the limited period which has elapsed since the top or bottom halves of the tree have been deflorated it seems that these parts bear out of phase with each other but one year. The two trees used in 1938 illustrate the limited information available. Tree 7–2 had the flowers removed in the top half in 1938; the top half was bearing in 1939, the bottom half was non-bearing. In 1940 both top and bottom halves had a heavy crop and in 1941 both top and bottom halves were non-bearing. The reverse treatment was given to tree 7–5, which had the flowers removed from the bottom half in 1938. This tree had the top and bottom out of phase in 1939, a crop on both top and bottom in 1940 and no crop on either half in 1941.

From 1933 through 1937 scaffold branches, comprising one-third or one-half of a tree, and whole trees were deflorated or defruited at weekly or 10-day intervals over a period of about 3 months following full bloom. In each year except 1935, fruit buds were differentiated on trees which were deflorated or defruited within a period of 30 to 40 days after full bloom. Beyond this period, defruiting was not effective in causing fruit buds to be differentiated. In 1935 no fruit buds were formed on any of the trees which were treated later than 14 days following full bloom. No explanation is had for this behavior. In 1937 branches of 2-inch size were deflorated or defruited at the same time as scaffold branches or whole trees; in addition one half of the 2-inch branches were ringed at the time of flower or fruit removal. Fruit buds were differentiated on the unringed branches up to 20 days after full bloom; on the ringed branches differentiation was caused until 40 days after full bloom, a period that agreed with that of defruited scaffolds or whole trees. Thus, ringing a 2-inch branch has extended the period during which fruit buds can be caused to differentiate when compared to an unringed branch of the same size but has not extended the period beyond that shown by defruited unringed scaffold branches or whole trees.

Mealiness and Quality in Delicious Apples as Affected by Certain Orchard Conditions and Storage Techniques[1]

By D. V. Fisher, *Iowa State College, Ames, Ia.*

THE Delicious apple is one of the most widely planted varieties in America, and in production constitutes about 15 per cent of the total apple crop of the United States. The variety requires special care in harvesting and storage in order for it to reach the consumer in firm, prime condition. Careless handling has resulted in a large proportion of the crop reaching the consumer in a condition of mealiness and poor flavor. Future success in marketing the increasing Delicious crop is contingent upon improved methods of handling and storing the fruit. This matter is considered one of the most important problems of the apple industry. The primary purpose of this investigation was to determine how certain orchard and storage techniques might be modified in order to improve the condition of the Delicious apple as it reaches the consumer market. The results reported upon are based on experimental work conducted at the Iowa Agricultural Experiment Station and the Dominion Experiment Station, Summerland, British Columbia.

Effect of Orchard Conditions and Maturity on Storage Quality

A survey of different orchards in four sections of the Okanagan Valley of British Columbia conducted over a period of 3 years, revealed that cultural conditions and seasonal growing temperatures markedly affected the flavor and keeping quality of the fruit. Much of the fruit harvested during the different seasons was deficient in characteristic Delicious flavor, due either to inadequate maturity as a result of too early picking, to retarded maturity of the apples on account of inadequate thinning of the fruit, or to an over-vegetative condition of the trees. As a general rule fruit harvested in a mature condition had characteristic Delicious flavor but was susceptible to mealiness, whereas fruit harvested immaturely was sweet, insipid and lacking in characteristic varietal flavor. Immature fruit, however, was much less susceptible to mealiness. A season with high summer and fall temperatures such as 1940 resulted in fruit of very good quality, whereas the low temperatures of the growing season of the year 1939 produced fruit of delayed maturity and poor quality.

Weekly harvesting of Delicious over a 4-week period showed no significant changes in sugar or acid content, although a marked improvement in flavor was noted in fruit of the last picking. At each picking, apples were cut equatorially and dipped in a standard iodine solution to ascertain the rate of starch disappearance from week to week. At the last date of picking a marked increase in starch loss was noted, a fact confirmed by chemical analysis. The results on starch were not completely conclusive and suggest the advisability of further work with the starch-iodine reaction as a maturity index.

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[1] This paper is an abstract of thesis No. 668, presented to the graduate faculty of Iowa State College, Dec., 1941, in partial fulfillment of the degree of Doctor of Philosophy. The complete thesis is on file at the library of Iowa State College, Ames, Iowa.

Journal Paper No. J962 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 668.

EFFECT OF STORAGE TREATMENTS ON CHEMICAL COMPOSITION AND RIPENING

Delicious from the Okanagan district of British Columbia placed immediately after harvest at different temperatures ripened about three times faster at 60 degrees F than at 40 degrees F, and about 1.6 times faster at 40 degrees F than at 32 degrees F. After harvest, Delicious became eating ripe in 2 weeks at 60 degrees F; in 6 to 7 weeks at 40 degrees F; and in 9 to 12 weeks at 32 degrees F. Delicious apples were mealy and overripe in 5 to 6 weeks from picking when held at 60 degrees F; in 15 to 16 weeks when held at 40 degrees F; and in 24 to 27 weeks when held at 32 degrees F. At 30 to 32 degrees F, the best temperature for storing Delicious, results indicated that for best eating quality this variety should not be stored longer than 16 weeks. Experiments in which Delicious were placed in cold storage after 1, 2 and 3 weeks delayed storage at 60 degrees F indicated that even 1 week's delay greatly shortened the potential keeping life of the fruit.

Respiration rates for Delicious were determined at 60 degrees F, 40 degrees F, and 32 degrees F. Respiration rate at 60 degrees F was double that at 40 degrees F and three times that at 32 degrees F. Sugar losses through respiration during the storage life of the fruit at all three temperatures amounted to roughly 1 per cent of the fresh weight at time of picking. At 60 degrees F, respiration intensity reached its climacteric about 5 days after picking, while apples stored at 40 and 32 degrees F showed no distinct climacteric.

In this investigation disappearance of starch and the hydrolysis of protopectin to soluble pectin were found to be useful physiological indicators of the progress of ripening in Delicious apples. Determinations were made at regular intervals during the storage period with fruit stored at 60, 40 and 32 degrees F to ascertain the influence of temperature upon these changes. After 4 weeks storage at 60 degrees F, Delicious showed about the same soluble pectin value as that of fruit held for 19 weeks at 40 degrees F. At the end of 19 weeks at 32 degrees F fruit showed about the same soluble pectin value as that of fruit in the second to third week of storage at 60 degrees F, and only slightly more than half that of fruit held at 40 degrees F for a similar period of time. The hydrolysis of the pectic substances contained in the cell walls was evidently closely associated with softening and development of mealiness; for with increasing soluble pectin values of the fruit there was a corresponding softening in flesh texture.

Disappearance of starch in Delicious as measured by dipping freshly cut equatorial cross-sectional surfaces of apples in a dilute iodine solution, proved a valuable index of the progress of ripening. In order to represent different stages in starch disappearance in a concise manner, a series of eight photographic standards was prepared, showing the starch picture in Delicious apples at regular intervals, from time of picking, until full ripeness when all starch had disappeared. Rate of starch disappearance followed a consistent trend, hastening as the temperature of storage increased. Attainment of eating ripeness was not marked by complete disappearance of starch, for when Delicious first reached eating ripeness, regardless of storage temperature, the starch-iodine picture of the fruit was intermediate between that of stages 3 and 4. However, the apples remained in firm eating condition until stage 7 was reached, where only a ring of starch remained around the outer periphery of the apple. It is suggested that the application of this test for detection of "lots" of Delicious apples in commercial storages, which have been delayed in storage, or stored at unsuitable temperatures, may prove of distinct value to storage operators. Tests on numerous commercial samples have indicated a close relationship between firmness of flesh and stage of starch disappearance.

RESULTS OF STORING DELICIOUS APPLES IN CONTROLLED ATMOSPHERES

In this study controlled atmosphere storage of Delicious apples has been investigated in some detail. Work by British and American investigators with controlled atmosphere storage has revealed that with many varieties increased concentrations of carbon dioxide accompanied by decreased oxygen in the storage atmosphere has produced marked effects in slowing down metabolic processes and prolonging storage of apples.

Preliminary experiments in 1937–38 with different $CO_2:O_2$ atmospheric mixtures produced by the respiration of Delicious in closed containers, and regulated by controlled ventilation, gave significant leads. Mixtures of 5.0, 7.5 and 10.0 per cent CO_2 in the presence of 15.0, 12.5 and 10.0 per cent O_2 were used at temperatures of 32 and 40 degrees F. Apples held under these atmospheres from time of harvest, and removed from storage on March 23, became mealy faster than fruit stored in ordinary air at similar temperatures. The pressure test also revealed that air-stored fruit was firmer than treated fruit. In the fruit held under 10 per cent CO_2 some of the apples showed flesh browning. Flavor of apples stored in controlled atmospheres, deteriorated faster than that of fruit stored in air, and scald was greatly increased by the modified atmosphere treatments.

Further experiments in 1938–39 and 1940–41 were carried out using atmospheres artificially prepared from compressed gas cylinders. The gas mixtures were flushed continuously over the fruit. The composition of the atmospheres was as follows:

Treatment	Percentage of Gases		
	CO_2	O_2	N_2
1	5.0	2.5	92.5
2	0.0	2.5	97.5
3	5.0	25.0	70.0
4 (Air)	0.0	20.0	80.0

Representative samples of extra-fancy medium size mature apples were used for the experiments. The first year's work was done at the Iowa Agricultural Experiment Station, and the second year's work at the Dominion Experiment Station, Summerland, British Columbia. The fruit was placed in storage at 32 and 40 degrees F under the above treatments immediately after harvest, and removed to air in late February. In both seasons it was the opinion of six unbiased judges that the fruit from the No. 2 treatment was superior in firmness and condition to that of other treatments and was closely followed by that of the No. 1 treatment. Pressure tests confirmed these observations. Ground color of the skin of the fruits in treatments Nos. 1 and 2 was greenish in shade, while that of treatments Nos. 3 and 4 was yellowish. At time of removal from storage, fruit of treatments Nos. 3 and 4 was almost mealy. This was particularly true for air-stored fruit at 40 degrees F. Fruit of treatment No. 2 remained in firm eating condition about 10 days longer than fruit given other treatments.

Briefly, storage of Delicious apples in atmospheres containing 2.5 per cent O_2 and 97.5 per cent N_2 at 32 or 40 degrees F inhibited softening, retarded changes in ground color of skin and greatly increased storage life as compared with air-stored checks held at 32 degrees F. Moreover such treatment resulted in no undesirable flavor or aroma, and in no tendency toward loss of capacity to ripen with characteristic Delicious quality, when the fruit was removed from storage. Storage of Delicious apples in atmospheres containing 5 per cent CO_2 with O_2 above the 10 per cent level caused the apples to become mealy; whereas 5 per cent CO_2 with 2.5 per cent O_2 did little harm.

Chemical analyses of fresh and preserved tissue of the apples given different treatments were carried out. These determinations were for pectin, sugars, starch, acid and alcohol-insoluble residue. In the soluble pectin determinations, made only in the 1940–41 season, very significant differences were noted between different lots at time of removal of the fruit from storage to air at 60 degrees F. Hydrolysis of protopectin in cell wall thickenings to the soluble pectin form was notably retarded by each of the three controlled atmospheres in comparison with air storage. This was most marked in the No. 2 treatment, a fact which explains differences in pressure test and eating test observations mentioned previously. Fruit form treatments Nos. 1 and 2 showed close to the same soluble pectin value at time of removal to air storage as found at time of picking. However, air-stored fruit showed pectin values several times as high, especially at 40 degrees F. Under controlled atmospheres there were but slight differences between the soluble pectin content of fruits stored at 40 and 32 degrees F; whereas with air-stored fruit, pectin values at 40 degrees F were approximately double those at 32 degrees F. Analyses of similar lots of fruits for soluble pectin 17 days later indicated that initial differences in soluble pectin content had largely disappeared.

Analyses of apples for sugars, acids and alcohol-insoluble residue, both at time of removal of fruit from storage and after periods at 60 degrees F in air, failed to reveal any significant differences in chemical composition between fruit stored in air, or in any of the controlled atmospheres.

RESULTS OF WAXING DELICIOUS APPLES ON STORAGE QUALITY

Waxing of Delicious apples with a commercial brand of wax emulsion delayed development of mealiness, improved storage life but resulted in the appearance of a peculiar type of skin scald differing somewhat from typical apple scald.

Time Interval Between Full Bloom and Fruit Maturity for Several Varieties of Apples, Pears, Peaches and Cherries[1]

By H. B. TUKEY, *New York State Agricultural Experiment Station, Geneva, N. Y.*

IN THE course of a series of studies on the development of the fruit of the sour cherry (9, 11) and of the peach (8) comparisons of curves for growth of the fruit were made both with different varieties during the same growing season and with the same variety in different growing seasons. It was found possible to integrate the growth curves for several different seasons on the basis of structural development of the fruit. That is, whereas the dates of blossoming and of fruit maturity might vary widely in different seasons, the periods of fruit growth designated as Stages I, II, and III (8, 9) and the curves of growth could be superimposed, to show considerable similarity.

Data presented by Magness *et al.* (3), Magness and Haller (4), Ellenwood (1), and Ryall, Smith, and Pentzer (5), indicate the value of the elapsed interval from bloom to fruit maturity as an index of fruit harvest, and Magness and Haller (4) suggest that the length of the growing season is probably the most important fundamental factor in determining the adaptability of a variety to a particular region.

Following these suggestions, this paper attempts to record some of the facts dealing with the growth periods of apple, pear, peach, and cherry fruits at Geneva, New York, and to give time intervals that have been observed with a number of varieties. The intervals between full bloom and fruit maturity were compiled from the Station records of blossoming and of picking dates, from 1903 to 1938, and centering mostly about 1911 to 1926.

During this period of time a number of different individuals have participated in the collection of the data. Standards for dates of bloom and of fruit maturity have, however, been fairly uniform. Trees were judged to be in full bloom when the maximum number of flowers were fully open. Cherry fruits were judged mature when they had reached the color characteristic of the variety, usually approaching softening, and later than the date of "commercial maturity". Peach fruits were judged mature when the ground color had changed from green to yellow, approaching softening, and later than the date of "commercial maturity". Apples and pears were judged mature when the ground color had changed from green to yellowish comparable to good commercial maturity.

RESULTS AND DISCUSSION

The data are given in three tables. In Table I is listed a representative number of varieties of apples, cherries, peaches, and pears, giving the number of seasons for which records are included, the shortest, longest, and average time intervals between full bloom and fruit maturity for the reported seasons, and the maximum variations in bloom-

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[1] Journal Article No. 467 of the N. Y. State Agricultural Experiment Station.

TABLE I—INTERVALS BETWEEN FULL BLOOM AND FRUIT RIPENING AND MAXIMUM SEASONAL DIFFERENCES FOR SEVERAL VARIETIES OF APPLES, PEARS, PEACHES, AND CHERRIES

Variety	Number of Seasons	Length of Season			Maximum Seasonal Differences		
		Shortest (Days)	Longest (Days)	Average (Days)	Between Blossoming Dates (Days)	Between Dates of Maturity (Days)	Between Elapsed Intervals From Bloom to Maturity (Days)
				Apples			
Alexander	3	105	110	108	14	16	5
Arkansas	2	137	144	141	8	10	7
Arkansas Black	2	132	139	135	9	8	7
Baldwin	4	134	138	135	8	6	4
Barringer	2	130	138	136	7	9	8
Baxter	2	118	125	121	5	7	7
Ben Davis	4	134	138	136	7	7	4
Bietigheimer	3	103	108	105	27	25	5
Bismarck	2	119	126	120	5	5	7
Black Ben Davis	3	134	140	136	5	6	6
Black Gilliflower	2	130	136	134	6	7	6
Boiken	3	139	143	141	6	18	4
Canada Baldwin	2	132	139	135	4	4	7
Chenango	6	103	115	106	25	16	12
Collamer	3	120	128	123	6	10	8
Cortland	3	125	130	128	6	8	5
Crimson Beauty	9	79	88	82	21	28	9
Deacon Jones	3	144	145	145	4	6	1
Delicious	4	129	134	132	5	4	5
Early Harvest	5	74	84	77	12	15	10
Early McIntosh	4	88	94	90	10	12	6
Esopus Spitzenberg	4	132	136	134	5	6	4
Excelsior	5	96	111	106	18	28	15
Fall Pippin	6	122	127	124	14	16	5
Fameuse	2	123	126	124	3	3	3
Fanny	5	98	112	106	23	30	14
Golden Delicious	3	132	140	138	6	8	8
Gravenstein	4	110	120	114	13	15	10
Green Newtown	3	144	148	146	4	4	4
Grimes Golden	2	132	135	134	4	4	3
Hubbardston	2	132	135	134	7	5	3
Hoadley	2	109	111	110	2	2	2
Holland Pippin	3	120	127	122	12	16	7
Hume	2	130	139	134	4	5	9
Jonathan	3	131	136	134	8	7	5
Lodi	2	74	80	76	6	6	6
McIntosh	5	124	129	127	11	11	5
Maiden Blush	3	130	136	132	11	7	6
Northern Spy	5	138	144	143	8	6	6
Northwestern Greening	2	144	145	145	8	7	1
Oldenburg	4	90	104	98	11	18	14
Opalescent	3	125	130	127	5	8	5
Pewaukee	3	135	144	140	4	13	9
Primate	8	82	104	87	17	16	12
Pumpkin Sweet	2	102	106	104	5	9	4
Red Astrachan	8	80	89	86	24	19	9
R. I. Greening	8	131	138	135	11	16	7
Rome	6	136	142	140	14	14	6
Roxbury	3	147	151	149	8	10	4
Stayman Winesap	3	143	147	145	5	6	4
Sutton	3	133	136	134	5	3	3
Tolman Sweet	3	134	138	137	4	3	4
Tompkins King	5	132	138	134	13	17	6
Twenty Ounce	3	120	128	122	6	10	8
Wagener	3	136	140	137	8	10	4
Walker Beauty	4	135	139	136	13	7	4
Wealthy	9	103	116	109	28	21	13
Winter Banana	3	131	137	133	6	4	6
Young America	9	105	116	106	29	22	11
Wolf River	4	94	109	107	8	14	15
York Imperial	2	137	138	138	7	8	1
				Peaches			
Belle of Georgia	6	120	132	122	22	13	12
Carman	7	103	115	113	28	26	12
Chili	6	140	145	144	14	12	5
Crosby	6	135	145	142	29	30	10
Early Crawford	3	118	130	118	29	16	12
Elberta	11	126	138	128	31	13	12
Greensboro	9	82	102	91	27	31	20

TABLE 1—(*Concluded*)

Variety		Length of Season			Maximum Seasonal Differences		
	Number of Seasons	Shortest (Days)	Longest (Days)	Average (Days)	Between Blossoming Dates (Days)	Between Dates of Maturity (Days)	Between Elapsed Intervals From Bloom to Maturity (Days)
Peaches							
Hiley	6	122	134	126	18	9	12
Late Crawford	6	128	136	133	31	27	8
Krummel	3	157	166	165	18	19	9
Mikado	11	83	94	88	28	21	11
Rochester	7	103	118	104	27	31	15
Salwey	6	159	166	162	29	29	7
Triumph	7	94	108	100	30	18	14
Ward Late	3	139	144	142	18	19	5
Cherries							
Abbesse d'Oignies	8	60	71	66	22	19	11
Bing	5	60	74	71	16	21	14
Black Tartarian	7	49	63	57	16	29	14
Brassington	10	53	66	61	27	30	13
Brusseler Braune	3	71	73	72	8	6	2
California Advance	3	41	51	49	22	12	10
Carnation	6	58	68	65	19	17	10
Chase	9	59	74	69	30	31	15
Cleveland	5	52	62	54	25	18	10
Coe	17	43	54	50	25	23	11
Dikeman	5	66	78	72	28	30	12
Double Natte	7	53	62	55	30	32	9
Downer	8	62	70	68	15	12	8
Eagle	6	51	62	60	14	15	11
Early Purple	12	37	48	42	27	21	11
Early Richmond	17	47	57	50	28	25	10
Elkhorn	9	53	68	61	26	28	15
Empress Eugenie	7	50	66	55	15	20	16
English Morello	29	60	74	70	28	30	14
Eureka	7	54	66	62	28	33	12
Florence	7	46	58	52	18	24	12
Genesee	5	62	72	66	24	30	10
George Glass	4	55	66	61	19	16	11
Governor Wood	9	43	50	47	28	31	7
King Amerelle	5	49	60	51	16	21	11
Kirtland	12	46	61	52	26	30	15
Knight	12	44	55	51	29	28	11
Lambert	7	61	72	69	15	25	11
Late Duke	5	60	72	66	33	25	12
Louis Philippe	8	53	61	53	24	25	8
Lyons	5	40	52	46	27	21	12
May Duke	9	41	55	51	28	34	14
Mazel	6	56	67	65	30	30	11
Montmorency	14	54	64	62	29	25	10
Napoleon	6	67	74	68	16	14	7
Ostheim	6	58	70	67	16	21	12
Reine Hortense	6	48	62	53	27	26	14
Rockport	8	42	56	52	21	21	14
Royal Duke	9	53	66	62	30	24	13
Sklanka	9	46	58	54	29	22	12
Schmidt	9	62	74	72	19	21	12
Sparhawk	6	52	64	60	17	23	12
Spate Amarelle	6	55	68	66	14	24	13
Vladimir	9	60	72	70	25	21	12
Windsor	6	65	76	75	15	12	11
Yellow Spanish	6	60	70	67	17	12	10
Pears							
Bartlett	11	110	123	121	29	22	13
Bloodgood	5	88	100	90	30	26	12
Clapp Favorite	3	111	118	116	25	30	7
Early Harvest	9	84	104	92	28	16	20
Elizabeth	6	86	101	98	27	30	15
Flemish Beauty	2	126	136	133	15	6	10
Kieffer	12	146	148	147	12	12	2
Lawrence	2	146	148	147	12	10	2
Seckel	4	129	141	137	12	11	12
Sheldon	2	135	150	145	13	12	15
Souvenir du Congress	2	125	134	130	15	6	9
Sudduth	3	131	150	138	11	16	19
Tyson	3	110	118	113	13	21	8
Wilder Early	8	86	98	93	24	18	12

ing dates, in dates of maturity, and in elapsed time between full bloom and fruit maturity.

Variations in the Data:—Some care must be taken in interpreting the data. For example, the seasonal variations of certain varieties maturing at about the same time are apparently much greater than others, but this is not always a safe conclusion because the data do not cover the same seasons for every variety. The data for the English Morello variety, for example, cover 29 years, while those for the Brusseler Braune variety cover only 3 years. It is to be expected that wider differences in blossoming dates and maturity dates might be experienced with the longer series of records, as is true with the data for the 10-year period and the 30-year period presented by Ellenwood (1). Further, there were certain seasons which were exceptionally early or exceptionally late, as the season of 1915 which was very long and the season of 1911 which was very short. If the records for a given variety happen to include both of these years, the variation in comparison with a variety which did not include them would be expected to be much greater.

Some of the variations that occur in the data may perhaps be attributed to personal factors, that is, opinions as to just when a tree is in full bloom and when the fruit is mature. Further, there are some indications that late varieties of apples have as a general practice been picked perhaps too early in New York State. The approach of freezing fall weather may in some seasons, for example, have influenced the picking dates rather than any accurate measure of maturity.

Another factor is the characteristic of some varieties to blossom over a prolonged period, as the Rome apple, or to ripen over a long period as the Primate apple, making the determination of the exact dates of blossoming and of maturity somewhat uncertain. While these factors cannot be overlooked, it is doubtful that they are sufficient to seriously alter the general conclusions which may be drawn.

Comparison of Elapsed Interval and Calendar Date:—In spite of the variations and difficulties enumerated above, the intervals of elapsed time between full bloom and fruit maturity more closely approximate each other than do calendar dates, as shown in Table I. Thus, with the Clapp Favorite pear the blossoming date during the three seasons recorded has varied 25 days, the maturity date has varied 30 days, yet the elapsed time between blossoming and fruit maturity has varied only 7 days. Likewise, the Salwey peach has varied 29 days in blossoming date, 29 days in maturity date, and only 7 days in elapsed time between blossoming and fruit maturity. On the other hand, individual exceptions can be found, such as the Hiley peach, where the elapsed time between blossoming and maturity exceeds the variations for the maturity dates in the 6 years that records were kept.

Comparison of Elapsed Interval for Different Fruits:—The interval of elapsed time between blossoming and maturity is more nearly constant for the apple than for the other fruits studied, followed by the pear, the peach, and the cherry in that order. If an explanation is needed it may lie in the fact that the time interval from bloom to maturity is greatest with the most of apple varieties and least with most cherry varieties, also that the blossoming season for apples is generally later than for cherries. Both of these factors are discussed in following paragraphs.

Comparison With Other Data:—In general, the elapsed intervals given in the tables agree with other data for similar varieties under somewhat similar conditions. For example, Ellenwood (1) lists Oldenburg as having an average elapsed interval in Ohio of 92 days, Wealthy 112, and McIntosh 132, while in the accompanying tables the average elapsed intervals for Geneva have been not widely different, namely, 98 for Oldenburg, 109 for Wealthy, and 127 for McIntosh. Further, Magness *et al.* (3) lists Grimes as requiring 130 days from full bloom to fruit maturity in New York State, 140 for Jonathan, 137 for Delicious, and 145 for Baldwin, as compared with 134, 134, 132 and 135 respectively reported here. They list Baldwin as requiring 142 days in Ohio and 136 and 146 in different seasons in Massachusetts, as compared with 135 in these tables.

On the other hand, Ellenwood (1) lists the elapsed intervals in Ohio for Grimes as 147, Jonathan as 151, Delicious as 153, Baldwin as 161, Rome as 167, and Stayman as 168, whereas at Geneva they appear much shorter, namely, 134, 134, 132, 135, 140, and 145, respectively. It will be noted that the spread is much less in New York than in sections of longer growing season to the south and west.

Nor must it be assumed that the data as presented for Geneva, New York, will apply to other sections. Ryall, Smith and Pentzer (5), too, have shown that the intervals between full bloom and maturity for pears differ in different sections of the Pacific Coast. Also in the data for the apple presented by Magness *et al.* (3), there are considerable differences in the elapsed interval in different parts of the country, and Ellenwood (1) indicates a similar situation within the State of Ohio. Obviously the time of bloom, seasonal temperatures, soil moisture, sunlight, rootstock, and other factors play an important part in determining how many days elapse between bloom and fruit ripening.

Comparison of a Season of Early Bloom with a Season of Late Bloom:—That the intervals of elapsed time between full bloom and fruit maturity in different seasons more closely approximate each other than do calendar dates, is true whether the season is early or late. The Chenango apple, for example, (Table II) shows a difference of 25 days between dates of blossoming in an early season as compared with a late season and a difference in maturity dates of 24 days, yet there is a difference of only 3 days in the elapsed time between full bloom and fruit maturity during the two seasons. Likewise with the Bartlett pear there is a difference in date of blossoming of 15 days and a difference in date of maturity of 17 days, between an early and a late season, yet the difference in number of days between full bloom and fruit maturity for these two seasons is only 3 days. Again there is a difference of 16 days between dates of bloom and 14 days between dates of fruit maturity for similar seasons for the English Morello cherry, but there is a spread of only 2 days in elapsed time between full bloom and fruit maturity. The peach varieties show the same trend.

Comparison of Early-Maturing and Late-Maturing Varieties:—In

TABLE II—COMPARISON OF A SEASON OF EARLY BLOOM WITH A SEASON OF LATE BLOOM

Variety	Year	Blossoming Date	Date of Maturity	Interval (Days)
		Apples		
Chenango	1921 (early)	May 1	Aug 14	105
Chenango	1922 (late)	May 26	Sep 3	100
Crimson Beauty	1930 (early)	May 8	Aug 1	85
Crimson Beauty	1929 (late)	May 29	Aug 25	88
Rome	1911 (early)	May 12	Sep 26	137
Rome	1912 (late)	May 21	Oct 2	134
Young America	1911 (early)	May 1	Aug 28	119
Young America	1924 (late)	May 30	Sep 10	123
		Pears		
Bartlett	1921 (early)	Apr 25	Aug 23	120
Bartlett	1922 (late)	May 10	Sep 10	123
Souvenir du Congress	1921 (early)	Apr 25	Sep 6	134
Souvenir du Congress	1922 (late)	May 10	Sep 12	125
Wilder Early	1921 (early)	Apr 26	Aug 4	100
Wilder Early	1932 (late)	May 20	Aug 18	90
		Peaches		
Carman	1921 (early)	Apr 21	Aug 15	115
Carman	1922 (late)	May 20	Sep 12	115
Crosby	1920 (late)	May 22	Oct 7	138
Crosby	1921 (early)	Apr 23	Sep 8	138
Mikado	1921 (early)	Apr 24	Jul 21	88
Mikado	1924 (late)	May 21	Aug 16	87
		Cherries		
Black Tartarian	1913 (early)	Apr 26	Jun 18	53
Black Tartarian	1916 (late)	May 11	Jul 4	54
Early Richmond	1921 (early)	Apr 25	Jun 12	48
Early Richmond	1923 (late)	May 23	Jul 11	49
English Morello	1921 (early)	Apr 25	Jun 28	64
English Morello	1922 (late)	May 11	Jul 12	62

the comparison of early-maturing and late-maturing varieties (Table III) there appears to be a greater variation in total elapsed time from bloom to fruit maturity for early-maturing than for late-maturing varieties. The data presented by Ellenwood for Ohio (1) show a similar trend, though to a lesser degree. Such earlier ripening varieties of apple as Chenango, Early Harvest, Oldenburg, Excelsior, and Primate vary more in elapsed time between bloom and maturity than such later maturing varieties as Ben Davis, Deacon Jones, Northern Spy, Northwestern Greening, Roxbury, Wagener, and York Imperial.

Again, the elapsed time for the early-maturing Mikado peach during a 8-year period varies from 83 to 92 days or 9 days; while with the Crosby variety for a 6-year period it varies from 135 to 142 days, or 7 days. While this difference in days is not great, the proportionate difference based on the length of growing season of the two varieties appear large. That is, a 9-day variation for a variety maturing 83 days from full bloom is 9.2 per cent, whereas a similar variation for a variety maturing 135 days from full bloom is 6.6 per cent. This feature, no doubt, makes the differences seem greater for an early-maturing variety than actually they are.

It would not be surprising, however, for early-maturing varieties to show greater variation than late-maturing varieties. In the first place, the earliest-maturing variety is one in which, with few exceptions, the period between full bloom and fruit maturity is shortest (6, 8). Accordingly, variations from the normal temperatures occur-

TABLE III—COMPARISON OF EARLY-MATURING AND LATE-MATURING VARIETIES

Year	Blossoming Date	Date of Maturity	Interval (Days)
Primate Apple (Early-Maturing)			
1921	Apr 28	Jul 27	90
1933	May 17	Aug 4	79
1934	May 18	Aug 6	80
Rome Apple (Late-Maturing)			
1911	May 12	Sep 26	137
1912	May 21	Oct 2	134
Early Harvest Apple (Early-Maturing)			
1915	Apr 30	Aug 5	97
1924	May 23	Aug 18	87
1930	May 8	Aug 8	92
1933	May 13	Aug 5	84
Bartlett Pear (Late-Maturing)			
1921	Apr 25	Aug 23	120
1922	May 10	Sep 10	123
1929	May 12	Sep 5	116
Mikado Peach (Early-Maturing)			
1921	Apr 24	Jul 21	88
1922	May 9	Jul 31	83
1923	May 21	Aug 9	80
1924	May 21	Aug 16	87
1930	May 6	Aug 4	90
1931	May 9	Aug 2	85
1932	May 15	Aug 5	82
1933	May 13	Jul 30	78
Crosby Peach (Late-Maturing)			
1919	May 13	Sep 25	135
1920	May 22	Oct 7	138
1921	Apr 23	Sep 8	138
1922	May 9	Sep 24	140
1923	May 22	Oct 4	135
1924	May 20	Oct 9	142

ring for short intervals during the growing season are more likely to be reflected in the early-maturing fruit, whereas they are more likely to be ironed out in a fruit having a longer period of development.

In the second place, as the studies of Lilleland (2) with the apricot have shown, it is the earliest stage of fruit development which is most affected by temperature. He enclosed growing fruits in heated cages and in shelters and found that the three stages of development of the fruit and of the embryo were markedly altered. The fruits matured 22 days earlier in shelters, but this earlier maturity was brought about largely by its effect upon Stage I of fruit development which was shortened from 46 days to 24 days. Stage II lasted 44 days for treated fruits and 49 days for untreated, actually a slower development for the treated fruits. Stage III lasted 28 days for treated fruits and 24 days for untreated, or a shortening of this period by only 4 days by treatment. Taking Stages II and III together, the total elapsed time was 73 days for the untreated fruits and 72 days for the treated, a decrease of only 1 day due to treatment, as contrasted with the shortening of Stage I by nearly half — 22 days.

Accordingly, since Stage I is similar for the varieties in a given class whether they be early-maturing or late-maturing (7, 8, 9), and since Stage II is characteristically short in an early-maturing variety, the effect of high and of low temperatures would be more apparent in the early-maturing than in the late-maturing variety.

Local Climatic Influences and Spread of Bloom:—The ease of integration of growth curves for peaches and cherries experienced (11) at Geneva, New York, may be altered by the general characteristic climate of a region. That is, it was observed that samples of peaches furnished at weekly intervals from full bloom to fruit maturity by Dr. T. J. Harrold of Georgia differed in several respects from samples taken at Geneva, New York. Among these was the greater spread in bloom of the several varieties in Georgia as compared with those growing in New York. Whereas the peach bloom for the several varieties extended over a period of only 1 or 2 days at Geneva, New York, it extended at least 10 days in Georgia. In other words, fruits at Geneva were fertilized and began development at almost the same time in a given season, as contrasted with wider spread in Georgia, thus favoring more uniform and more easily compared growth curves at Geneva.

Development of Plant Parts as Indexes:—In conclusion, it may not be out of place to again suggest that such orchard operations as fruit thinning, irrigation, spray coverage, and cultivation might well be based upon the development of plant parts, such as the fruit rather than upon calendar dates (10). Among the points of orientation already suggested, applying to drupe fruits, are places in Stages I, II, and III of fruit development, the point at which the embryo begins its period of rapid development, and the point at which the pit begins to harden. The entire study suggests the value of more complete data on the growth of fruits and of fruit parts and their application to horticultural practices.

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Days from Bloom as an Index of Maturity for Apples

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THERE has been a tendency for apple growers to pick certain varieties rather early and the Federal-State Inspection Service is called upon to certify when the apples are mature. The indexes of maturity given by Magness, Diehl, and Haller (3) were for optimum maturity and not for the earliest possible picking maturity; the indexes given, such as ground color, ease of separation of the fruit from the spur, and pressure test, were not sufficiently definite or satisfactory. Hesse and Hitz (2) also report these and other indexes of maturity as unsatisfactory for Jonathan and Grimes Golden apples and suggest the possibility of using a starch test for Jonathan.

At the request of the United States Agricultural Marketing Service the present studies were undertaken on the reliability of indexes of maturity for Williams, Jonathan, Grimes Golden, and Yellow Newtown varieties, with particular emphasis on early picking maturity. As used in this paper maturity does not refer to optimum maturity, but to that stage in the apples development at which it could be picked with satisfactory storage and dessert quality.

Magness *et al* (4) found that the number of days from full bloom to maturity was rather constant for each of the varieties used by them, under different seasonal conditions at a given locality and even under the widely varying climatic and soil conditions of widely separated localities. Ellenwood (1) has presented data showing the number of days from bloom to first picking of 10 varieties for 30 years at Wooster, Ohio. In most instances the difference between the season of the fewest and the season of the greatest number of days from bloom to harvest was in excess of 20 days. The Ohio results would indicate that the seasonal variation was too great for days from bloom to be used as an index of maturity. However, the periods given were from bloom to harvest and it is likely that at least some of the variation may have been due to harvesting at different stages of maturity. It is possible that in seasons of short elapsed time from bloom to harvest the apples were picked in a considerably less mature state than in seasons of long elapsed time.

With three varieties of pears, Ryall, Smith, and Pentzer (5) found the elapsed period from bloom to maturity to be rather consistent, particularly within a district, and they consider this a valuable adjunct to present maturity indexes for pears.

MATERIAL AND METHODS

During three seasons Williams, Jonathan, Grimes Golden, and Yellow Newtown apples were obtained from orchards in the localities indicated in Tables I to IV. Several pickings at approximately weekly intervals were made each season from the same trees and samples of each picking were held in 32 degrees F storage throughout the storage season for the variety. They were then post-ripened 1 week at 70 degrees and inspected for storage disorders and dessert quality. On the basis of these inspections the date of earliest picking maturity was determined. The results in Tables I to IV show the condition of the apples at this picking date together with the elapsed time from full bloom. At full bloom about 75 per cent of the side blossoms were open and the center blossom was generally shedding its petals.

At each picking samples were taken from two plots of one or more trees in each orchard and determinations made on each sample separately and the ranges in pressure test and ground color shown in Tables I to IV represent the averages of the duplicate samples. Firmness was determined on the pared cheeks of 20 apples per sample with the United States Department of Agriculture pressure tester having a 7/16-inch plunger. Ground color was determined by comparison with a United States Department of Agriculture standard color chart, with the addition of a deeper green color than number 1 which was designated zero (0). A transverse section of the fruit was tested for starch by the qualitative iodine-potassium iodide method and the percentage of the surface showing starch was estimated.

RESULTS

Williams:—Although the two localities from which the Williams apples were obtained were less than 30 miles apart the conditions were distinctly different. The orchard near Berlin, Maryland, had much older trees on a heavier soil than did the one at Salisbury, and because of the closer proximity to the ocean the summer temperatures were generally appreciably lower. At both localities in 1939 and 1940 the time from bloom to maturity was about 70 days (Table I). In 1938 the first picking was not made until 80 days from bloom and the fruit was considered mature. Although a picking 2 or 3 days earlier might have been considered mature also, the apples that season would probably have been found distinctly immature at 70 days from bloom. Because of the very early bloom in 1938 or for other reasons, the elapsed time from bloom to maturity was not the same as that of the two later seasons. For the three seasons the pressure test at maturity varied from 20 to 23.5 pounds and was of no value as an indicator of maturity; the ground color showed no appreciable change and was as dark as or darker than the greenest stage (No. 1) of the standard color chart; likewise the seed color and starch test showed no change in maturity.

TABLE I—CONDITION OF WILLIAMS APPLES AT EARLIEST MATURITY

Locality	Year	Bloom Date	First Mature Date	Elapsed Time Bloom to Maturity (Days)	Pressure Test (Pounds)	Ground Color (Number)	Seed Color	Starch Test
Salisbury, Maryland.....	1938	Apr 18	July 7	80	21.4 to 21.1	0.4 to 0.7	White	100
Salisbury, Maryland.....	1939	Apr 29	July 8	70	21.9 to 20.0	0.8 to 1.0	White	100
Berlin, Maryland	1939	May 2	July 11	70	23.5 to 23.4	0.8 to 1.0	White	100
Salisbury, Maryland.....	1940	May 9	July 18	70	22.9 to 21.9	1.0	White	—
Berlin, Maryland	1940	May 15	July 26	72	22.2 to 22.1	1.0	White	100 to 75

Jonathan:—Apples from orchards near Martinsburg and Kearneysville, West Virginia were grown on heavier soils and generally exposed to higher temperatures than those from near Berlin, Maryland. In 1939 and in 1940 the date of full bloom was the same at Kearneysville and Berlin, but it was much later in 1940 than in 1939. In all three seasons and at all localities the elapsed time from bloom to maturity was about 130 days (Table II). In 1938 the picking made 134 days from bloom was considered mature. Although the apples were rather subject to storage scald, indicating immaturity, they were at the lower limits of firmness for storage, were more yellow at maturity than the apples in subsequent seasons, and had less starch. In 1939 apples from Berlin, Maryland were definitely mature when picked 134 days from bloom and probably were mature enough for picking several days earlier. In 1940 at Kearneysville pickings were made at 123 and 135 days from bloom. The picking at 123 days was of questionable maturity as the dessert quality was only fair. On the other hand, that made at 135 days developed appreciable breakdown indicating that it was approaching overmaturity. An intermediate picking, at least 125 days from bloom, was indicated for early maturity.

The pressure test at maturity varied from 15.1 to 18.4 pounds and was not sufficiently consistent to serve as an index of maturity. The ground color was generally between 1.5 and 2.0 but the color change was not sufficiently rapid or marked to be satisfactory. The seeds turned brown at various lengths of time previous to maturity. In a number of instances about 75 to 50 per cent of the transverse cross section showed starch at maturity. However, in other instances the starch had disappeared to this extent considerably before the apples were mature so this also was unsatisfactory as an index of maturity.

TABLE II—CONDITION OF JONATHAN APPLES AT EARLIEST MATURITY

Locality	Year	Bloom (Date)	First Mature (Date)	Elapsed Time Bloom to Maturity (Days)	Pressure Test (Pounds)	Ground Color (Number)	Seed Color	Starch Test
Martinsburg, West Virginia.	1938	Apr 21	Sep 2	134	15.1	1.9 to 2.3	Brown	10
Kearneysville, West Virginia.	1939	Apr 25	Sep 1	120	18.4 to 17.8	1.6 to 1.8	Brown	80 to 50
Berlin, Maryland	1939	Apr 25	Sep 6	134	17.8 to 16.7	1.7	Brown	80 to 50
Kearneysville, West Virginia.	1940	May 11	Sep 13	125 +	17.1 to 15.7	1.5 to 1.9	Brown	70 to 50
Berlin, Maryland	1940	May 11	Sep 19	131	17.2 to 15.7	1.7 to 1.8	Brown	60 to 25

Grimes Golden:—Grimes Golden apples were obtained from three localities in each of three seasons. The date of full bloom varied from April 13 to May 10 and the date of earliest maturity from August 30 to September 23. In general, 135 to 140 days elapsed between full bloom and maturity regardless of local and seasonal conditions. The least number of days from bloom to maturity is given for Crozet, Virginia in 1940 (Table III). In this instance 30 to 60 per cent of the apples dropped previous to the picking made at 131 days from bloom. Thus, picking previous to this time would have been necessary in order to save the crop although the storage lots did not indicate that the

TABLE III—Condition of Grimes Golden Apples at Earliest Maturity

Locality	Year	Bloom (Date)	First Mature (Date)	Elapsed Time Bloom to Maturity (Days)*	Pressure Test (Pounds)	Ground Color (Number)	Seed Color	Starch Test
Crozet, Virginia.	1938	Apr 13	Aug 30	139	18.9 to 18.6	1.8 to 1.2	Brown	100
Kearneysville, West Virginia.	1938	Apr 20	Sep 2	135	23.8 to 23.0	1.0	Brown	100
Salisbury, Maryland.....	1938	Apr 15	Sep 1	139	20.9 to 19.1	1.1 to 0.8	Brown	100
Crozet, Virginia.	1939	Apr 17	Aug 31	136	19.6 to 18.7	1.1 to 1.0	Brown	100 to 90
Kearneysville, West Virginia.	1939	Apr 25	Sep 11	139 +	21.0 to 19.7	1.1	Brown	100
Berlin, Maryland	1939	Apr 22	Sep 6	137	22.4 to 22.1	1.0	Brown	100 to 95
Crozet, Virginia.	1940	May 1	Sep 9	131 +	21.1 to 19.0	1.5 to 0.9	Brown	100 to 90
Kearneysville, West Virginia.	1940	May 10	Sep 23	136	21.1	1.3 to 1.1	Brown	100
Berlin, Maryland	1940	May 9	Sep 19	133 +	19.4 to 19.2	1.2	Brown	100 to 90

*Pickings were made at the elapsed time indicated but plus signs indicate that the apples were of questionable maturity and a few days delay was desirable.

apples were mature as they were of only fair dessert quality and developed considerable scald in storage. Since it was not possible to make a later picking this date was given as the date of maturity.

There was considerable variation in pressure test at maturity and no indication that this could be used as an index of maturity. The ground color at maturity was not distinctively different from the greenest color on the chart and could not be used as a maturity index. The seeds turned brown at various periods before harvest and there was little or no disappearance of starch so these indexes were also unsuitable.

Yellow Newtown (Albemarle Pippin):—The Yellow Newtown variety was obtained from only one locality; where it is grown commercially and where the commercial harvest begins rather early (frequently around August 25). The Yellow Newtown is a long-storage variety but when picked too early it tends to scald badly even when packed with oiled paper. On the other hand, the apples may drop badly under Virginia conditions if left on the trees until best dessert and storage quality are attained. This occurred in these experimental plots in both the 1939 and the 1940 seasons. Apples of this variety are also reputed to develop skin spotting when left on the trees too long, although this was not apparent in these experimental lots. In general the results in Table IV indicate that at least 150 days should elapse from bloom before this variety is picked. Although the apples were not considered mature (of satisfactory dessert and storage quality) until nearly 150 days from bloom, this would not have allowed sufficient time for

TABLE IV—Condition of Yellow Newtown (Albemarle Pippin) Apples at Earliest Maturity

Locality	Year	Bloom (Date)	First Mature (Date)	Elapsed Time Bloom to Maturity (Days)	Pressure Test (Pounds)	Ground Color (Number)	Seed Color	Starch Test
Crozet, Virginia.	1938	Apr 13	Sep 13	153	21.5 to 21.2	1.1 to 1.0	Brown	90
	1939	Apr 17	Sep 20	156	22.6 to 21.5	1.2 to 1.1	Brown	80 to 70
	1940	May 2	Sep 25	146	20.4	1.0	Brown	100 to 25

picking in 1940 as rather severe dropping was apparent in the picking made 154 days from bloom. This early drop may have been due to very heavy rains which caused considerable leaf injury early in the harvest period.

There was not sufficient change in pressure test or ground color for these factors to be of value as maturity indexes. The seeds were brown at various intervals previous to maturity and the starch test was not consistent enough to be of value.

SUMMARY AND CONCLUSIONS

A study of indexes of early picking maturity for Williams, Jonathan, Grimes Golden and Yellow Newtown apples grown under middle Atlantic conditions has shown the pressure test, ground color, seed color and starch test to be unreliable for these varieties.

Regardless of locality and seasonal variations the number of days from bloom to maturity has been rather constant during three seasons, and has been a more reliable index of maturity than the other factors studied.

On the basis of these results harvest should not begin until at least 70 days from full bloom for Williams, 130 days for Jonathan, 135 days for Grimes Golden, and 150 days for Yellow Newtown. Optimum maturity would be somewhat later than this.

In order to further test and extend these results cooperative arrangements have been made with a number of widely separated experiment stations to conduct similar studies on these and other varieties of apples. Additional results may show an influence of certain climatic or cultural conditions on the number of days from bloom to maturity.

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The Relation Between Diameter and Fresh Weight of Developing Peach Fruits

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PREVIOUS data regarding the change of shape of peaches have been presented as ratios of one diameter to the others (1, 2, 3). This type of calculation may hide, obscure, or accentuate changes in the diameters used as dependent variables and further does not offer any opportunity to compare all diameters to the same variable. It would seem that some variable, reflecting fruit development, and independent of diameter changes, might be more desirable as a reference figure. Fresh weight of the fruit is probably a summation of the growth of the fruit and might, therefore, serve as a reference variable, although it could be reasoned that certain changes such as that in specific gravity could occur without any change in the diameter.

The investigations reported in this paper were begun as a part of the studies on splitting of peaches in an effort to obtain a concept of the relative changes in shape that occurred during the development of the fruit.

Materials and Methods

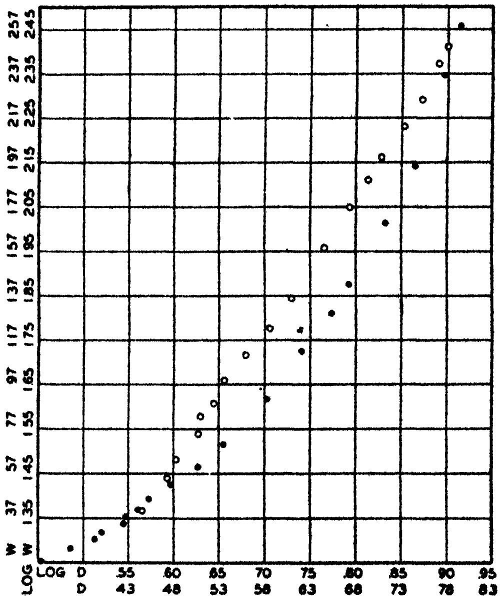

Fig. 1. California Packing Corporation Sims 1941. Suture diameter (closed circles) or its logarithm (open circles) plotted against the weight or its logarithm.

Random samples of 50 fruits each of a number of varieties were collected in each of the two leading California canning peach growing areas, Sutter and Stanislaus counties, and from the University Farm at Davis at about weekly intervals beginning 2 to 3 weeks before the pit began to harden and continuing until harvest. The fruits were placed in friction top tin cans, brought to the laboratory where the total weight in grams of the 50 fruits was determined and the three diameters, the suture, cross and length measured in millimeters with a vernier caliper. The suture diameter was determined as the largest diameter through the plane of the sutures, the cross, the largest diameter at right angles to the sutures and the length, the distance from the stem end to the base of the tip at the distal end. The suture and cross diameters of individual fruits could be measured with a rather high degree of accuracy but the same accuracy could not be attained with the length, perhaps because of the difficulty of estimating where to place the calipers at the base of the tip. From these data the average weights and the average diameters were determined.

RESULTS

When the average suture diameters of the seasonal collections are plotted against the average weights a smooth curve like that shown in Fig. 1 is obtained. When the logarithm of the diameter is plotted against the logarithm of the weight a straight line is obtained. The same situation holds for the cross diameter in which a smooth curve is obtained when this diameter is plotted against the weight and a straight line when the logarithms of the two variables are used. The relation between the weight (W) and cross or suture diameters (D) may then be expressed by the equation $W = bD^a$. This does not, however, occur when the length or its logarithm is plotted against the weight or the logarithm of the weight.

Fig. 2 shows two varieties of canning peaches in which the logarithms of the average cross and suture diameters are plotted against the logarithms of the average weight. The Paloro is one of the earliest of the canning varieties to ripen; the Phillips, one of the latest to mature, ripens about 5 weeks after the Paloro. It will be seen that the curve of the suture and cross diameters has a regular slope throughout the period of development. The slope of the curve for the cross diameter is less than that of the suture which indicates, as they are plotted here, that the cross diameter has grown more rapidly throughout the season of sampling than the suture.

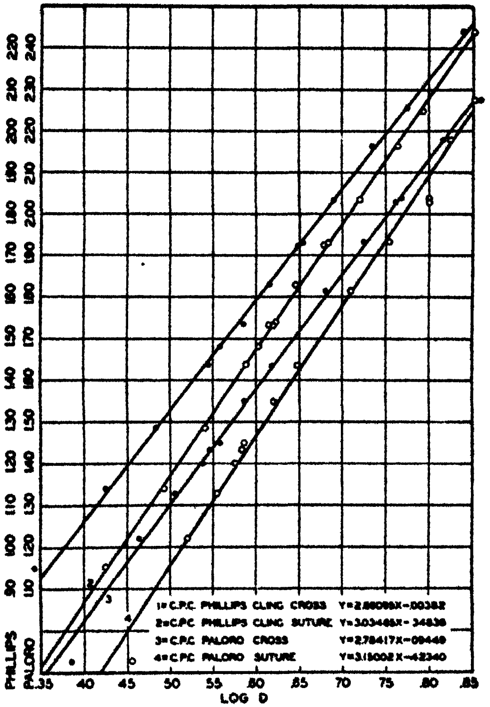

FIG. 2. The logarithm of the suture and cross diameter plotted against the logarithm of the weight. California Packing Corporation Phillips Cling and Paloro 1941. The lines are for the calculated equations.

The same regularity of slope is not shown for the length diameter (Fig. 3). This curve can be divided into three distinct parts: the first, formed by the

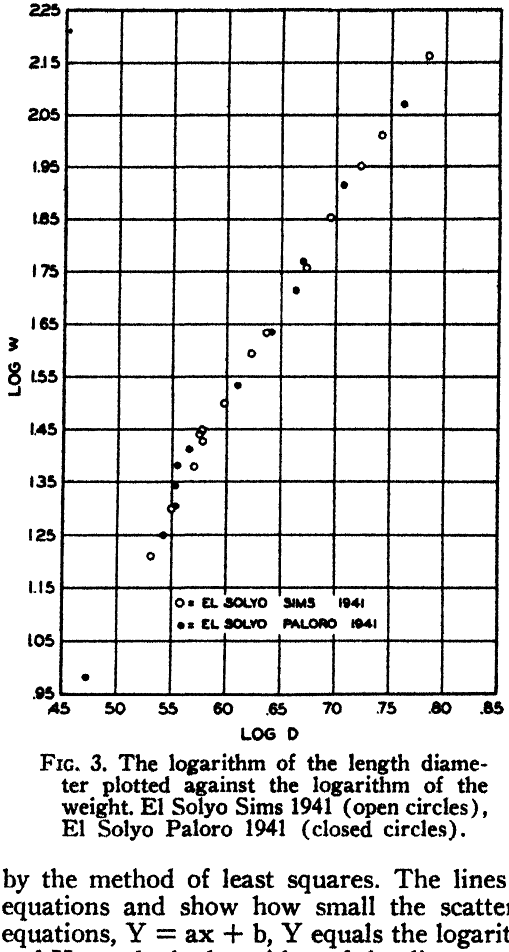

FIG. 3. The logarithm of the length diameter plotted against the logarithm of the weight. El Solyo Sims 1941 (open circles), El Solyo Paloro 1941 (closed circles).

first few samples, has a slope somewhat steeper than that of the suture or cross diameter; the second part with a very steep slope, almost 90 degrees, covers a period of two to four samplings; the third part has a slope less steep than the first but more steep than that of the curves for the suture or cross diameters. This situation has been found in all the varieties and seasons investigated. The period during which this change of slope is occurring is at the time the pit is hardening. The steeper slope of all parts of the curve of the length diameter shows that this diameter always grows less rapidly in proportion to the weight of the fruit than do either the suture or the cross.

The straight line equation for the data of the cross and suture diameters has been calculated by the method of least squares. The lines in Fig. 2 are from these equations and show how small the scatter is about them. In these equations, $Y = ax + b$, Y equals the logarithm of the weight in grams and X equals the logarithm of the diameter in centimeters. Essentially the same degree of scatter shown about the line for the equation of best fit has been found for all varieties and replications investigated.

The equations of like diameters for replicate samples within a variety for any season, or for the same variety in different seasons are very much alike. Table I shows the values of a and b for replicate samples within a variety and for the three years 1935, 1937, and 1941, in which these data have been obtained. Within a variety at least there is very little variation in the slope of the lines and it would seem that even among some varieties there is very little difference. Table II shows the same data in a different manner. In this table the values for x, the diameter of the fruit have been calculated from the equations when a value of Y, the weight, has been assumed. In this table two values of Y have been assumed ($Y = 15$ grams, $Y = 150$ grams). These values are about the average weights of the first and harvest samples respec-

TABLE I—VALUES OF "A" AND "B" IN THE EQUATION $Y = ax + b$ IN WHICH Y = LOG WEIGHT (GRAMS) AND X = LOG DIAMETERS (CENTIMETERS)

Year and Location	Suture Diameter		Cross Diameter	
	a	b	a	b
	Phillips Cling			
1935 Sutter County	3.19525	–.43235	2.64247	.01788
1937 El Solyo	2.99244	–.29992	2.59501	.05952
Sutter County	3.04520	–.33292	2.56954	.09070
University Farm	2.99668	–.28636	2.53595	.07930
1941 C.P.C.	3.03465	–.34838	2.66095	–.00362
El Solyo	3.07192	–.37317	2.63473	.01473
	Paloro			
1935 Sutter County	3.06532	–.35148	2.64184	–.02049
1937 El Solyo	2.95363	–.28043	2.70844	–.03628
Sutter County	3.07027	–.34946	2.70637	–.00751
University Farm	2.99038	–.31511	2.71669	–.02235
1941 C.P.C.	3.15002	–.42340	2.78417	–.09449
E. Solyo	3.05727	–.36072	2.78004	–.09414
	Peak			
1937 El Solyo	2.97429	–.26995	2.75815	–.07404
Sutter County	3.02350	–.30369	2.71584	–.02771
1941 C.P.C.	2.95756	–.27686	2.62697	.00201
	Gaume			
1935 Sutter County	2.95091	–.30480	2.61410	–.02380
1937 Woodbridge	2.97846	–.31802	2.65782	.02364
Sutter County	2.94243	–.29232	2.72586	–.02917
1941 C.P.C.	3.00891	–.33118	2.68899	–.02759
	Halford			
1937 Sutter County	2.96399	–.29350	2.61338	.06191
El Solyo	2.99412	–.30156	2.73873	–.07398
1941 El Solyo	2.99836	–.30717	2.71779	–.06229
C.P.C.	3.02630	–.32532	2.88956	–.06223

tively. It will be seen that there is very good agreement among the calculated values for X for both these assumed values of Y. Fig. 4 shows the graphs of the equations for the Gaume variety for the three seasons 1935, 1937, 1941, and illustrates how much alike these equations are. Fig. 5 shows the suture diameter for two seasons and two locations of the Phillips Cling plotted together, again showing the type of agreement there is among the individual data.

DISCUSSION

The data which have been presented show that there is a relation between the weights and suture or cross diameter of the peach which conforms to the type $W = bD^a$. The average weights and suture or cross diameters of 50 fruits picked at random at frequent intervals throughout the season show a very small scatter about the straight line equation calculated from their logarithms. The agreement among replications of a variety in a season or among different seasons is so close as to suggest that an equation calculated from the data obtained from a series of well-chosen samples may be sufficient to show the changing relation between either of these two diameters and the weight of the fruit. It is not known, however, just how much alike these three seasons were and it may well be that further experience with seasons that are much different may show that such an equation obtained from

TABLE II—DIAMETERS OF FRUITS IN MILLIMETERS OBTAINED BY SOLVING THE EQUATIONS FOR LOG WEIGHT-LOG DIAMETER WHEN CERTAIN WEIGHTS, 15 GRAMS AND 150 GRAMS ARE ASSUMED

Year and Location	Suture Diameter When Weight Equals		Cross Diameter When Weight Equals	
	(15 Gms)	(150 Gms)	(15 Gms)	(150 Gms)
	Phillips Cling			
1935 Sutter County	31.9	65.5	27.4	65.6
1937 El Solyo	31.1	67.2	26.9	65.4
Sutter County	31.3	66.6	26.4	64.8
University Farm	30.8	66.3	27.1	67.1
1941 C.P.C.*	31.8	67.9	27.7	65.9
El Solyo	31.9	67.6	27.6	66.1
	Paloro			
1935 Sutter County	31.5	66.9	28.4	67.8
1937 El Solyo	31.1	67.9	28.0	65.6
Sutter County	31.4	66.5	27.4	64.2
University Farm	31.5	68.1	27.6	64.5
1941 C.P.C.	32.2	66.9	28.6	65.4
El Solyo	31.8	67.6	28.6	65.6
	Peak			
1937 El Solyo	30.6	66.4	28.4	65.4
Sutter County	30.9	66.1	27.7	64.8
1941 C.P.C.	31.0	67.5	28.0	67.2
	Gaume			
1935 Sutter County	31.8	69.3	28.8	69.4
1937 Woodbridge	31.4	68.1	27.1	63.7
Sutter County	31.6	69.0	27.6	64.4
1941 C.P.C.	31.6	68.1	28.0	66.0
	Halford			
1937 Sutter County	31.3	68.1	26.7	64.4
El Solyo	31.5	68.5	28.6	66.3
1941 El Solyo	31.2	67.3	28.6	66.6
C.P.C.	31.3	67.1	28.6	66.6

*California Packing Corporation.

one season cannot be applied to another.

If the data of these three seasons should agree with those of other seasons a satisfactory calculation of either the average weight or average suture or cross diameter could be made when one of the variables is known. These data apply to average sizes or weights of a sample that seems large enough to represent the population from which it was taken. It is not yet known whether these equations could be used to calculate the dimensions or weights when the distribution of sizes of the individual members of a population on a given date were under consideration.

The equations which show the seasonal relation between the logarithm of the suture diameter and the logarithm of the weight are very similar to that showing the relation between the volumes of spheres and their diameters. The latter equation when $Y = \log V$ and $X = \log D$ is $Y = 2.99992X - .28093$.

No explanation is had for the behavior of the curve when the logarithm of the length is plotted against the logarithm of the weight. The method of plotting these data is such that an increase in the slope of the curve indicates a smaller increase in diameter growth when compared to increase in weight. This curve might be divided into three

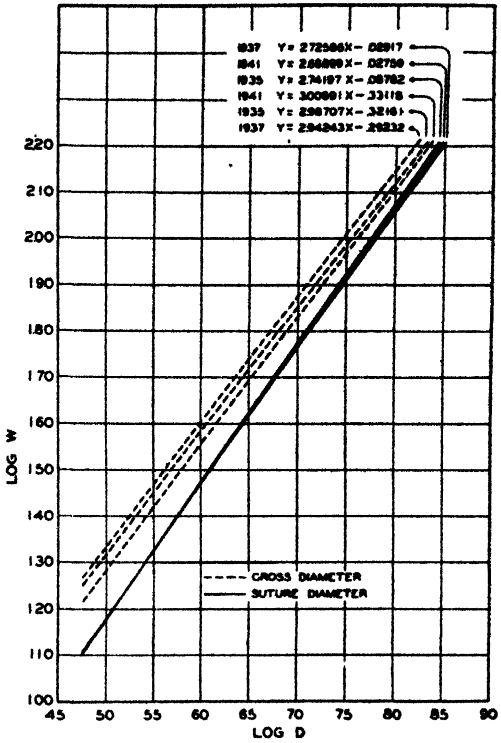

FIG. 4. The logarithm of the cross and suture diameters plotted against the logarithm of the weight (Gaume variety, 1935, 1937, 1941).

parts, the first consisting of the samples taken prior to pit hardening when there is a definite slope; the second during the time when the pit is hardening and during which so little change has taken place in the length that the slope seems to approach 90 degrees; and the third part during which the slope has changed again and become less steep than either the first or second part of the curve. The fact that this behavior has been found in all samples investigated suggests that the phenomenon is associated with the development of the fruit, and it may not be a coincidence that these changes take place at about the time split-pit is occurring.

SUMMARY

Samples of 50 fruits, taken at about weekly intervals from a few weeks prior to pit hardening until maturity, have been weighed and each of the diameters, suture, cross and length determined.

When the average cross or suture diameter is plotted against the average weight a smooth curve results which becomes a straight line when the logarithms of the variables are used.

The relation between the average length diameter and the average weight is not as regular as that between the other two diameters and the weight. The slope of the curve resulting when the logarithm of the length is plotted against the logarithm of the weight changes twice during the season. Both of these changes occur during the time the pit is hardening and at about the time split-pit would occur.

The scatter of the points about the calculated line of best fit is such as to suggest that 50 fruits is a sufficient number to represent the population from which they were taken.

The data presented in this paper and the equations calculated from them are for average values of various diameters and weights taken at about weekly intervals during the season. They may not represent

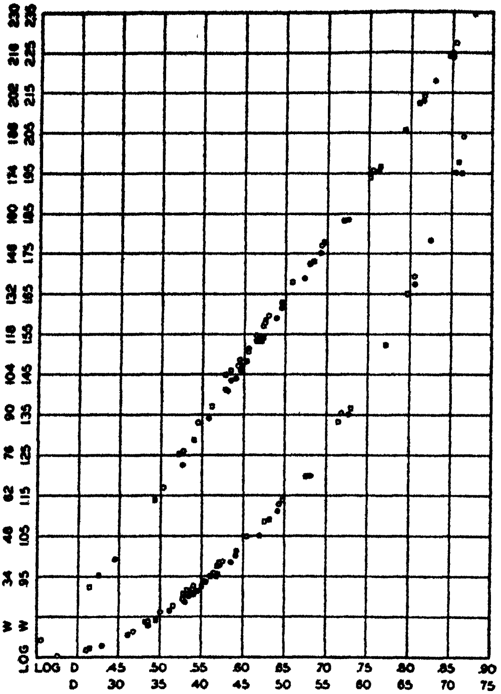

FIG. 5. The suture diameter or its logarithm plotted against the weight or its logarithm. Phillips Cling variety, El Solyo 1937 and 1941, California Packing Corporation 1937 and 1941. Open circles, El Solyo 1937; closed circles, El Solyo 1941; open squares, California Packing Corporation 1937; closed squares, California Packing Corporation 1941.

the relation existing between these variables for the various sized fruits that are found on a given date.

There is excellent agreement among the equations for replications within a variety either from different locations in one season or among seasons.

When compared to the weight the cross diameter has the greatest seasonal change of the three diameters, the suture next and the length the least.

Either the suture or the cross diameter would seem to be suitable for calculating the seasonal relation between them and the weight of the fruit. This would be especially true if data from additional seasons should agree with those already investigated.

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Additional Studies of the Acidity and Tannin Content of Mature Peach Fruits[1]

By M. A. BLAKE, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

THE acid content of the ripe fruits of a considerable number of varieties of peaches grown at New Brunswick, New Jersey, in 1940 was determined and reported (1). This work was repeated during the summer of 1941. It so happened that the weather during the two seasons was in marked contrast. The spring of 1940 was one of the latest ever experienced at New Brunswick. The trees not only bloomed later but the foliage was thin because of the percentage of weak light in early spring. Again in August, so much dull wet weather occurred at one time that peaches were lacking in color and shipping qualities. In late summer, temperatures were too cool to mature some varieties well.

In contrast to 1940, the early spring of 1941 was unusually warm. During April, 1941 the mean was 56.1 degrees F, the highest daily maximum was 92 degrees F and there were only six cloudy days. In April, 1940 the mean was 45 degrees F, the highest daily maximum 75 degrees F and the number of cloudy days was 16.

EFFECT UPON TREES

The warm days of April 1941 resulted in an exceptionally rapid leaf and flower development. The strong light of the many clear days favored maximum carbohydrate synthesis, the green fruits were relatively large at the pit hardening stage, and there was almost a total absence of peach scab and brown rot where standard spraying was practiced. Each variety matured its fruit about 14 days earlier in 1941 than in 1940 except in very late summer when the difference in some varieties was sometimes 10 to 12 days.

ACIDITY DETERMINATIONS

The majority of the acidity determinations in 1940, particularly of the fruit of varieties ripening before Elberta, and all of the determinations in 1941 were made by a pomology student, Frank Gilbert. The method of sampling and of making the determinations in 1941 were the same as those employed in 1940 and previously described (1).

CLASSIFICATION OF RELATIVE ACIDITY

Following the studies of acidity made in 1940, it was suggested that the fruits of the various varieties be classified on the basis of pH into 1, very acid; 2, medium acid; and 3, low acid. Further studies in 1941 in cooperation with Dr. J. F. Pessel, a physician of Trenton, New Jersey appeared to indicate that it would be more desirable to use titratable acidity rather than pH as a basis for such classification.

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[1] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University.

The following classes of acidity for peach fruits is based on the number of milliliters of N/10 NaOH required to titrate a 10 milliliter sample of freshly extracted peach juice, and is suggested to replace the one reported in 1940: 1, very low acid, 7 and less; 2, low acid, 7 to 10; 3, medium acid, 10 to 13; and 4, high acid, 13 and above.

Some Results of Two Years' Study

Acidity determinations were made on soft-ripe fruits of several hundred varieties and unnamed seedlings both in 1940 and 1941. Determinations were also made with fruits of varying degrees of ripeness. Only selected data from that work are reported in this paper in order to keep it within bounds. All of the results reported at this time apply to soft-ripe specimens of each variety. Although the seasons of 1940 and 1941 varied so much in climatic factors, including light,

TABLE I—Examples of Varieties of Peaches of Different Classes of Acidity at New Brunswick, New Jersey (1940–41)

Variety	Titratable Acidity		pH	
	1940	1941	1940	1941
Class 1, Very Low Acid, pH 7 or Less				
Estella	4.95	4.50	4.46	4.57
Muir	6.39	6.21	4.19	4.42
Class 2, Low Acid, pH 7 to 10				
Colora	8.01	8.31	4.42	3.96
Halehaven	8.70	9.11	3.94	3.96
Kalhaven	8.80	9.60	3.80	3.98
Polly	8.70	9.51	3.82	3.84
Summercrest	7.72	8.79	3.96	4.10
Up-to-Date	8.50	7.05	3.99	3.82
Class 3, Medium Acid, pH 10 to 13				
Carman	10.02	11.12	3.81	3.72
Elberta	9.66	10.29	3.58	3.80
Golden Jubilee	10.45	11.93	3.99	3.68
J. H. Hale	10.71	11.68	3.61	3.69
Red Magdalen	10.30	10.39	3.85	3.56
Class 4, High Acid, pH 13 and above				
Fair's Beauty	13.52	13.62	3.55	3.63

TABLE II—Examples of Varieties of Peaches Which Varied Markedly in Acidity

Variety	Titratable		pH	
	1940	1941	1940	1941
Chili	7.50	10.69	3.99	4.02
Early Rose	9.21	12.11	3.79	3.69
Eclipse	5.13	8.99	4.80	4.00
Engle's Mammoth	9.60	10.18	3.92	3.68
George IV	8.54	12.30	4.22	3.70
Hiley	9.78	12.58	4.00	3.69
Late Crawford	9.40	15.99	3.88	3.59
Mamie Ross	10.68	14.10	3.68	3.44
Veteran	8.92	10.90	4.03	3.72

temperature, and moisture, that the varieties ripened 10 to 14 days earlier in 1941 and the color and the quality of the fruit were different, certain varieties developed about the same acidity each year.

In Table I, examples of varieties which showed a rather consistent degree of acidity for two years are given by classes of acidity.

Some Varieties Varied Markedly in Acidity

Peach specialists have observed, probably since ancient times, that some varieties of peaches vary markedly in acidity according to environmental conditions. Examples of varieties which showed marked variations in acidity at New Brunswick in the seasons of 1940 and 1941 are given in Table II.

TABLE III—Tannin Content of the Ripe Fruits of a Number of Varieties of Peaches at New Brunswick (1936–1941)

Variety	1936	1937	1938	1939	1940	1941
Mikado (June Elberta)	40	—	65	30	25	20
Japan Dwarf Blood	100	95	100	100	100	85
Greensboro	50	—	50	50	35	25
Marigold	20	—	10	30	25	35
Sunbeam	0	0	0	5	5	5
Rosebud	30	35	45	20	15	15
Raritan Rose	—	10	10	20	20	20
Goldfinch	20	35	40	30	5	20
Golden Jubilee	45	50	50	35	15	20
Triogem	35	30	—	25	20	15
Carman	35	20	35	70	20	15
Chinese Blood	100	100	100	100	100	100
Mamie Ross	35	20	35	30	30	20
Marquette	15	55	45	60	20	—
Ideal	30	40	25	40	30	—
Halehaven	30	—	55	30	20	30
Goldeneast	50	—	75	50	35	25
Eclipse	20	20	—	35	15	15
Kathryn	60	40	40	40	10	15
Hiley	5	15	25	—	60	15
Vedette	20	—	25	30	5	20
Veteran	15	35	30	20	20	25
South Haven	40	40	35	50	25	20
Belle	45	10	40	45	—	25
Summercrest	30	50	45	20	10	25
Polly	—	50	65	—	35	20
Primrose	25	40	50	—	70	20
Elberta	55	50	45	50	25	30
Chinese Cling	25	45	45	60	40	25
Japan G. G. Cling	45	35	60	65	90	35
J. H. Hale	45	55	45	50	30	25
Estella	30	35	35	40	35	20
White Hale	20	35	35	15	20	25
Lizzie	55	—	40	45	35	25
Iron Mountain	45	—	50	75	40	30

Catechol Tannin Content

Catechol tannin determinations of the ripe fruits of many varieties of peaches have been made at New Brunswick since 1936. The method of sampling and testing was reported previously (1). The data obtained for 34 varieties are given in Table III as a cross section of the entire list of varieties. The varieties are arranged according to the approximate season of ripening in order that the reader may readily contrast varieties of about the same season.

Chinese Blood has been used as the standard among varieties for maximum tannin. Japan Dwarf Blood is also very high in tannin. Sunbeam has been the consistent low tannin example in the named variety collection at New Brunswick.

Varieties of the Elberta and J. H. Hale types are rather high in tannin. It is an established fact that trees which become exceptionally high in carbohydrates tend to develop fruits exceptionally high in tannin for the variety. Therefore fruits produced upon trees injured by borers, rodents, or winter injury in such a manner as to have the effect of partial girdling tend to be high in tannin. However, where such variations in growth status are carefully avoided it has been found at New Brunswick that the fruits of some varieties fluctuate rather widely in tannin from season to season while others are relatively uniform. During the past 6 years at New Brunswick, New Jersey, the seasons of 1938 and 1939 were correlated with a rather high tannin content of peach fruits, whereas that of 1941 was correlated with a relatively low content.

As previously mentioned in this paper, the season of 1941 was characterized by exceptional warm and favorable weather for growth during early spring. In contrast, during the seasons of 1938 and 1939 at New Brunswick the trees experienced some rather low temperatures and dry conditions at times. The fact that such marked seasonal variations occurred from 1936 to 1941 provided an opportunity to contrast the annual behavior of a number of varieties under the environmental conditions which prevailed at New Brunswick, New Jersey and results are reported in Table III.

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The Effects of Curing, Curing Temperatures, and Date of Harvest on the Composition of Pecan Nuts

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Abstract

This material will be published in full in the *Journal of Agricultural Research.*

A STUDY was made of the effects of curing, including curing temperatures, and date of harvest on the composition of pecan nuts of two varieties, Western and Success.

Nuts were harvested at three stages of maturity, as determined by early, mid-season, and late harvest dates. Different lots of nuts of each variety and for each harvest date were cured at room temperature with and without the shucks attached, and at 0 to 2 degrees C, at 35 degrees C, and at 50 degrees C, without the shucks. The nuts were considered as cured when they had reached approximately constant weight. At each harvest date one lot of nuts of each variety was separated into shucks, shells, and kernels and samples were taken for analysis to determine composition at harvest. Shucks, shells, and kernels of all lots cured at room temperature, and shells and kernels of other cured lots were sampled for analysis as soon as curing was complete.

The important changes in composition of the tissues of the nuts occurring at the different harvest dates, and during the curing process, were as follows:

The amount of total sugars per kernel increased greatly in all kernels from early to late harvest dates, and also increased considerably during curing in kernels of nuts of the early and mid-season harvests, the greatest increase occurring in kernels of nuts cured at room temperature with the shucks attached. The least increase of total sugars during curing occurred in kernels of shucked nuts cured at 0 to 2 degrees and 50 degrees C. The amount of acid-hydrolyzable polysaccharides per kernel decreased during curing, and some of these substances probably were converted into sugars. The shucks lost a considerable amount of reducing sugars per shuck during the curing period, while an increase in acid-hydrolyzable polysaccharides occurred at the same time. This indicates that at least a portion of the reducing sugars was converted into acid-hydrolyzable polysaccharides during curing of the shucks. Some of these sugars may have been translocated to the kernels of nuts cured with the shucks attached, since the amount of total sugars per kernel increased more in such kernels than in those of nuts cured with the shucks removed.

There was no appreciable change in the amounts of any of the constituents of the shells at different dates of harvest or during curing at different temperatures.

The amount of organic nitrogen per kernel increased in the Success variety from early to late harvest dates, but not in the Western variety. This may indicate that protein formation occurs at later stages of kernel development in Success than in Western since most of the

organic nitrogen of kernels is contained in the proteins.

The amount of oil per kernel increased in both varieties from the early to the mid-season harvest dates, after which it remained practically constant. There was also a slight increase of oil in kernels of Western during the curing of nuts harvested early.

Kernels of nuts cured at 50 degrees C were very brittle, and the flavor was somewhat similar to that of partially roasted kernels. This was true of all nuts cured at 50 degrees C, regardless of the date of harvest. Kernels of nuts cured at 0 to 2 degrees C lacked sweetness of flavor, and the texture was flabby and tough, but the color was much lighter than that of kernels cured at the higher temperatures. The effects of the 0 to 2 degrees curing temperature were somewhat less pronounced with deferring of the harvest dates. Kernels of nuts cured at room temperature and at 35 degrees C appeared to be normal in flavor and texture regardless of harvest date.

Studies of the Premature Dropping of Pecan Nuts

By JOSEPH HAMILTON, *U. S. Department of Agriculture, Brownwood, Tex.*

ABSTRACT

This material will be published in full in the *Journal of Agricultural Research.*

STUDIES of the premature dropping of pecan nuts in central west Texas were made on the Schley, Western, Burkett and Mahan varieties during the seasons of 1935, 1936, 1937, and 1940, and on the Halbert, Sovereign, Success and Squirrel varieties during 1940.

Records of the dropping of the nuts were made during a period beginning approximately 2 weeks after pollination (May 6 to 15) and in most cases extending through the full season. In 1940 some clusters were bagged before the stigmas were receptive. After stigma receptivity had passed the bags were removed. Records of the time and rate of dropping of these unpollinated nuts were compared with similar records for open-pollinated nuts.

Practically all of the premature dropping occurred during a period from near the first or middle of May to the latter part of June in all varieties except the Halbert which maintained a fairly constant but very low rate of drop throughout the season. The period during which most of the nuts dropped corresponded to the period of drop of the unpollinated bagged nuts of the same varieties.

Most of the varieties used in the experiments dropped the nuts rapidly and mainly during a period from May 6 to 15 to the latter part of June. After this period the amount and rate of dropping was very low for the remainder of the season. The main period of dropping corresponds somewhat to the "May" drop of Woodroof, Woodroof, and Bailey (2) which they associated with lack of pollination of fertilization although it extended over a longer period of time, while the small amount of dropping for the remainder of the season corresponds to their "summer" drop.

The data obtained from the studies during the four years do not show definitely the causes of the premature dropping of pecan nuts. Woodroof (3) found that fertilization of the egg cells of the pecan occurred about 5 or 6 weeks after pollination, and this was later confirmed by McKay (1) who found fertilization occurring approximately 6 weeks after pollination. In the varieties reported here the amount of dropping that occurred later than 6 weeks after pollination varied from about 13 per cent to 58 per cent of the total drop that occurred during the period when unpollinated nuts dropped but it is not known whether any of the dropping was caused by lack of fertilization. It is extremely unlikely that any of the nuts that were not bagged failed to be pollinated because there was an abundance of pollen shed in the orchard throughout the blossoming periods.

The amount of premature dropping varied within a single variety from season to season, and with different varieties in the same season. The percentages of the nuts that dropped prematurely in four varieties during the four years 1935, 1936, 1937, and 1940, respectively, were as follows: Burkett 31.5 per cent, 16.0 per cent, 32.2 per cent, and 41.0 per cent; Schley 46.0 per cent, 23.0 per cent, 46.0 per cent, and 53.4 per cent; Western 40.0 per cent, 20.0 per cent, 14.3 per cent, and 22.0 per cent, and Mahan 69.5 per cent, 24.4 per cent, 30.0 per cent, and 35.8 per cent.

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The Effect of Magnesium Deficiency in Grapefruit Trees Upon the Composition of Fruit

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SYMPTOMS known to be associated with a deficiency of magnesium are of common occurrence in citrus in Florida. A detailed description of these plant symptoms, as they occur in the field, has been presented by Camp and Fudge (2). These authors have also presented a literature review and a complete bibliography pertaining to the subject of citrus malnutrition. Work has been in progress at the Florida Citrus Experiment Station during the past few years which shows that a deficiency of magnesium results in a decline in tree growth and yield and that when this deficiency is partially or wholly corrected by the application of magnesium bearing materials, tree growth and yield are increased greatly. That the composition of the fruit is adversely affected by a deficiency of this element has been indicated previously. Roy and Bahrt (5) presented data showing that the vitamin C content increased in the juice of oranges, and Fudge and Fehmerling (4) working with oranges and Cowart and Stearns (3) working with both oranges and grapefruit presented data showing that the total soluble solids, sugars, and vitamin C content increased in these fruits following the application of magnesium bearing materials to trees deficient in this element.

METHODS AND MATERIALS

The trees involved in this study had all developed a very severe deficiency of magnesium prior to the initiation of the present fertilizer program in December, 1937. This condition is readily understandable in view of the continued use of a fertilizer containing nitrogen, phosphoric acid, and potash only from the time the grove was set in 1925, on a Norfolk fine sand, a soil originally very low in magnesium content as well as one which is subject to rapid leaching. The nutritional program, other than that concerned with the amount of magnesium applied, has been identical in all the plots involved in this study. Since December, 1937, this program, excepting that concerned with magnesium, has been one which is, at present, recognized to maintain trees in good vigor and production on the light, sandy soils of Florida. The trees have received soil applications of fertilizer in the spring, summer, and fall in amounts totaling 40 to 45 pounds annually, analyzing as follows: $3\frac{1}{2}(N) - 6(P_2O_5) - 8(K_2O) - 2(MnO) - 1(ZnO) - \frac{1}{2}(CuO)$. An annual nutritional spray containing 3 pounds each of manganese sulfate, zinc sulfate, and copper sulfate, and 6 pounds of hydrated lime per 100 gallons of water was applied to all trees. Limestone has been applied at a rate of approximately 900 pounds annually; an amount sufficient to raise to and maintain the soil reaction at approximately pH 6.0. The nutritional elements were derived from the following sources, one-half of the nitrogen from nitrate of potash or from nitrate of soda and one-half from sulfate of ammonia, phosphorus from triple superphosphate, potassium from nitrate of potash and sulfate of potash, manganese from manganous sulfate, zinc from zinc sulfate, and copper from copper sulfate. With regard to the magnesium content of the fertilizer, the treatments in duplicate plots of both the Duncan and Marsh varieties are: (a) Application of a fertilizer not containing magnesium, plots 2 and 11, in which the trees continue to show very severe symptoms of magnesium deficiency; (b) application of a fertilizer containing 2 per cent magnesium oxide from magnesium sulfate, plots 3 and 10, in which the trees show slight symptoms of magnesium deficiency; and (c) the use of a fertilizer containing 4 per cent magnesium oxide from magnesium sulfate, plots 4 and 9, in which the trees are adequately supplied with magnesium as indicated by the absence of symptoms indicative of a deficiency of this element.

Samples of 25 fruit, each of the same size, were collected from trees in each plot of the Duncan, a seedy variety, and from the Marsh, a seedless variety, at approximately bi-weekly intervals. The plots contain seven trees of each of the above varieties all grown on rough lemon rootstock. The fruits were juiced with a power driven reamer, the juice strained through four thicknesses of cheesecloth, and aliquots taken for analysis. Total soluble solids were measured with a Brix hydrometer and the reading corrected to a temperature of 17.5 degrees C; acid was determined by titration with alkali and calculated as anhydrous citric acid; reducing sugars were determined using the essentials of the Shaffer and Hartmann method (8); and vitamin C was determined using the method of Bessey and King (3) and standardizing the sodium 2,6-dichlorobenzenoneindophenol solution against a known quantity of pure crystalline vitamin C. The total sugars were determined after inversion with acid, and sucrose calculated from the difference between the reducing and total sugars.

RESULTS

Data in Tables I and II are typical of the results obtained from analyses of fruit from trees deficient in magnesium compared with those in which the deficiency has been partially or wholly corrected. The data presented are for the 1940–41 season, a good crop year. Results of analyses of fruit from these trees during 1939–40 and 1941–42, years of lighter crops, are in agreement with those for the 1940–41 season, though the differences are of slightly smaller magnitude.

TABLE I—Effect of. Magnesium Deficiency Upon the Composition of Duncan and Marsh Grapefruit (January 14, 1941)

Plots	Treatment	Variety	Citric Acid (Per Cent)	Total Soluble Solids (Per Cent)	Reducing Sugars (Per Cent)	Sucrose (Per Cent)	Total Sugars (Per Cent)	Vitamin C Mg/100 Ml of Juice
2, 11	0 MgO	Duncan	1.68	10.55	3.19	1.96	5.25	39.6
		Marsh	1.42	9.02	3.14	1.86	5.10	35.0
3, 10	2 per cent MgO	Duncan	1.69	11.04	3.23	2.44	5.80	42.7
		Marsh	1.50	9.62	3.40	2.25	5.77	36.8
4, 9	4 per cent MgO	Duncan	1.76	11.58	3.80	2.82	6.77	45.6
		Marsh	1.52	10.00	3.56	2.23	5.91	37.1

TABLE II—EFFECT OF MAGNESIUM DEFICIENCY UPON THE TOTAL SOLUBLE SOLIDS CONTENT OF DUNCAN AND MARSH GRAPEFRUIT (SEPTEMBER, 1940, TO JANUARY, 1941)

Plots	Treatment	Variety	1940						1941
			Sep 13	Sep 26	Oct 9	Oct 24	Nov 6	Nov 22	Jan 14
2, 11	0 MgO	Duncan	8.65	9.09	9.18	9.63	9.92	9.95	10.55
		Marsh	8.38	8.48	8.57	8.83	8.73	8.91	9.02
3, 10	2 per cent MgO	Duncan	9.08	9.55	9.92	10.20	10.62	10.55	11.04
		Marsh	8.47	8.97	8.98	9.15	9.27	9.29	9.62
4, 9	4 per cent MgO	Duncan	9.20	10.07	10.28	10.70	10.80	10.94	11.58
		Marsh	8.79	9.39	9.30	9.40	9.32	9.55	10.00

The fruit from trees which are devoid of symptoms indicative of a magnesium deficiency, plots 4 and 9, are higher in total soluble solids and sugars and slightly higher in vitamin C and citric acid content than fruit from trees in which the magnesium deficiency has been partially corrected, plots 3 and 10, Table I. Likewise, the fruit from trees in plots 3 and 10 are higher in these constituents than fruit from trees which still show symptoms indicative of a very severe deficiency of magnesium, plots 2 and 11. The difference in the latter case has averaged greater from year to year but both are of approximately the same magnitude for the 1940–41 season. Similar analyses were made at two other dates during the season and are in agreement with those presented. That these differences are present at any time during the season is indicated by the content of total soluble solids in the juice of fruit from the trees receiving the three treatments, from September, 1940, to January, 1941, Table II. Cowart and Stearns (3) have shown that the differences in composition between fruit from orange trees deficient in magnesium and that from trees adequately supplied with this element increase in magnitude as the season advances. Over a 3-year period with grapefruit, this same trend is indicated, although not nearly so clearly as with oranges. The differences in total soluble solids content of fruit from trees of the three treatments are slightly less during early season than those present at later dates (Table II).

DISCUSSION AND CONCLUSIONS

From the data presented it may be concluded that a magnesium deficiency in grapefruit leads to a lowering of those components which are to a large extent responsible for internal quality of fruit. This conclusion is substantiated by analyses of fruit from these same plots during two other seasons. Data from other plots concerned with a comparison of the composition of fruit from trees deficient in magnesium with those adequately supplied with this element are also in agreement with the data included in this paper. The effect on composition is of considerable importance when considered from the standpoint of consumer acceptance of the fruit. Individuals tasting the fruit from trees deficient in magnesium and that from trees adequately supplied with this element have invariably indicated a preference for the fruit from trees in the latter category. The greater total soluble solids and sugar contents of the fruit from trees which receive adequate amounts of magnesium are, no doubt, largely responsible for this preference. The improvement in internal quality of fruit following the application of magnesium bearing materials to trees deficient in this element undoubtedly results from the great increase in leaf area and from an increase in efficiency of the foliage on these trees.

These data further substantiate the recommendations of the Citrus Experiment Station regarding the use of magnesium in the fertilizer program with citrus in Florida, based on the amount of magnesium required for the maintenance of favorable tree growth and production.

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Seasonal Growth and Dry Matter Accumulation in Winesap Apples

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FRUIT growth measurements and dry matter increases have been studied of many kinds of fruits, notably those in the genus Prunus. Records of volume enlargement rate of apples as associated with environmental conditions are numerous, but little has been published on the relationship between dry matter accumulation and volume increase of this fruit.

In conjunction with studies on some possible factors influencing seasonal variations in periodicity of enlargement in Winesap apples (3), it was of interest to obtain information on the rate of dry matter deposition in seeds and cortex tissues of apple fruits throughout the growing season. The work was conducted during the summer and early fall of 1939 at Wenatchee, Washington.

METHODS

On May 22, or 28 days after full bloom, a large number of apples on a single Winesap tree were measured and those having equal circumferences were tagged. Subsequent samples for dry matter determinations were in all cases taken from these tagged and measured fruits. A high percentage of those originally tagged showed a remarkable uniformity in circumference enlargement rate during the experimental period. Sample collections were usually made at 10-day intervals although a longer time elapsed between some collections in the latter part of the season. Between 15 and 20 apples comprised a sample, the number selected being governed by the size of fruit. Volume measurements of whole small fruits were obtained by displacement in mercury. After July 7, water was substituted for the mercury.

Determinations for total solids in both seeds and flesh were made by distillation in tuluol by a modification of the methods described by Bidwell and Sterling (1). In securing a composite sample a wedge of tissue extending from the calyx to the stem cavity was cut from each fruit. After weighing, the volume of the sample was found by displacement in toluol, precautions being taken to prevent evaporation of toluol between readings. Both toluol and sample were then transferred quantitatively to the distilling flask for the determination.

RESULTS

The seasonal trends of fruit enlargement rate, and fresh weights of fruit and seeds (Fig. 1), should be considered primarily from the standpoint of comparison at given sampling dates. An accurate growth curve can only be determined by measuring the same fruits throughout the season. Volume increments as obtained by the present methods, however, are in fair agreement with those found in other investigations with Winesap apples (3).

Relationships between fresh weight and volume of entire fruits are

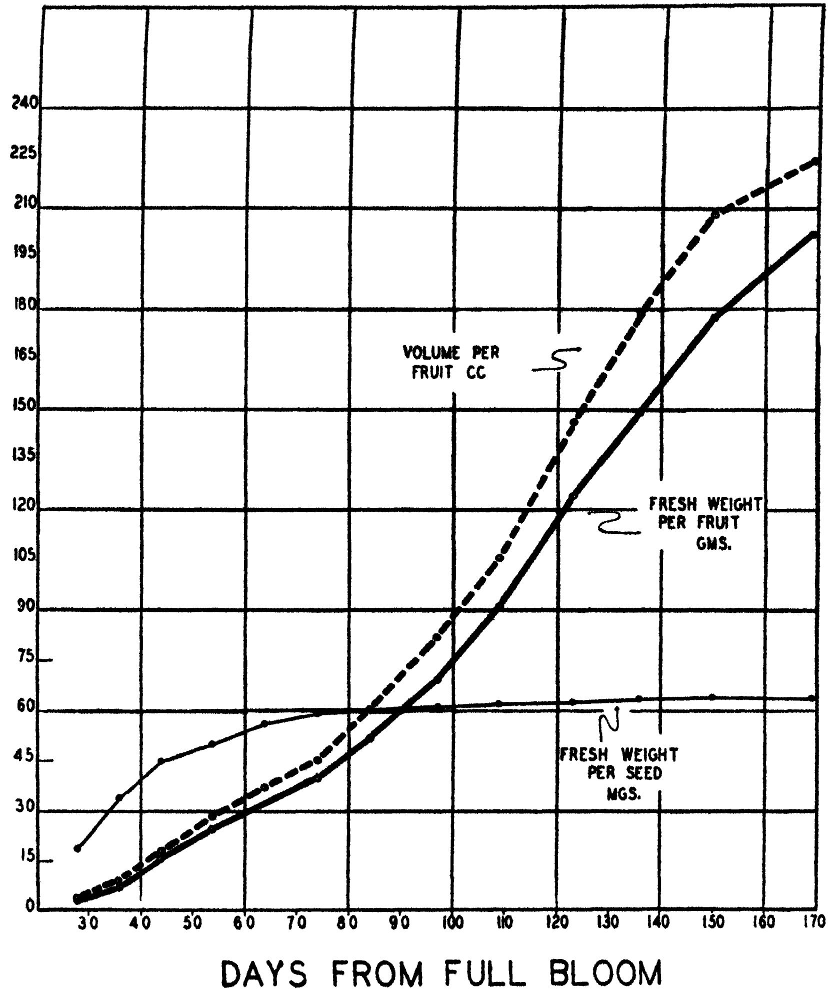

FIG. 1. Seasonal relationship of volume per fruit, fresh weight per fruit, and fresh weight per seed, of Winesap apples at Wenatchee, Washington, 1939.

shown to be relatively uniform with the possible exception of the last sample taken 169 days from full bloom. Both curves show a decrease in rate between 150 and 169 days, but the decline in volume is somewhat greater than the decline in fresh weight of the same fruits. Based on density figures from other points on the two curves the deviation from the calculated volume is 5.5 per cent. This divergence from the rather constant proportions found in earlier samples cannot be fully accounted for with the present data. It is felt, however, that some physiological process not here apparent might be responsible for the increased density at this stage of development. A still later sample would have been helpful in interpreting this departure but rapid fruit abscission prevented further sampling. No water core was present in the samples.

The curve for dry matter per fruit (Fig. 2) shows total solids to accumulate increasingly in rate as the apples grew in volume. After 97 days from full bloom there was an acceleration of deposition reaching a maximum rate during the last 19 days before harvest.

With the exception of some irregularities, dry matter in 100 grams of fresh cortical tissue did not vary greatly during the season. The

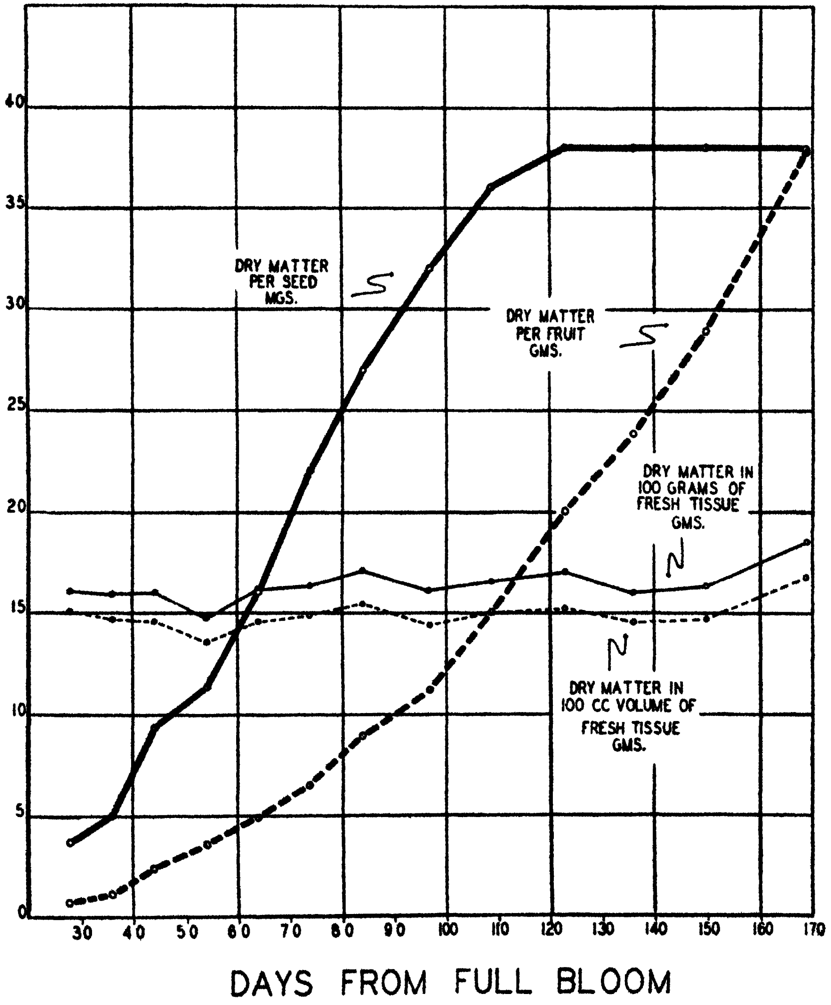

FIG. 2. Seasonal relationship of dry matter per fruit, dry matter in 100 grams of fresh cortical tissue, and dry matter per seed, of Winesap apples at Wenatchee, Washington, 1939.

most conspicuous and perhaps significant change occurred in the last sample which shows a rather rapid increase in total solids as the fruit reached harvest maturity. The curve for dry matter in 100 cubic centimeters volume of fresh cortical tissue has a configuration almost identical with that for dry matter in 100 grams of fresh tissue. The space between the two curves is a relative index of internal atmosphere in the flesh, and this is quite uniform in all samples except when the fruits were quite small.

Increments for fresh weight and for dry matter per seed are shown in Figs. 1 and 2, respectively. At 74 days from full bloom seeds attained 92 per cent of their final fresh weight, while the maximum was not reached until about 150 days. Dry matter per seed, on the other hand, shows a steady gain up to 123 days from full bloom, after which it remained constant. At 123 days the seed coats were completely brown.

CONCLUSIONS

Volume-weight relationship studies of Winesap apples indicate that the density of whole fruits remains approximately at unity during the growing season until the approach of harvest maturity when a slight increase in density is evidenced. It is believed that this departure from the relatively uniform density exhibited in less mature fruits may be accounted for by the physical and chemical changes associated with maturation. The acceleration in dry matter accumulation during this period (150 to 169 days from full bloom) is probably not due to photosynthetic activity of the leaves alone, but in addition, hydrolysis of polysaccharides within the fruit may contribute to the gain in total solids, thus increasing the density of the flesh. Hydrolysis of starch is known to occur in apples as they reach harvest maturity (2).

Enlargement of apples in the later growth stages is sometimes considered to be largely due to water intake and to an increase of intercellular air. Data from the present study indicate that this is not normally the case. Dry matter was found to accumulate in relatively large quantities just prior to abscission and the percentage of internal atmosphere of the flesh remained practically constant after 44 days from full bloom.

Seeds attained their maximum dry weight 123 days after bloom or 46 days before harvest, and at this time the seed coats were brown. This is additional evidence that seed color in late maturing varieties of apples is of little value in determining the optimum picking date.

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Pectic Changes in Jonathan Apples as a Measure of Ripening Under Differential Carbon Dioxide Treatments[1]

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IT IS known that the pectic constituents of stored fruits change from the insoluble form, known as protopectin, to soluble pectin. With certain storage treatments this change is frequently marked and is accompanied with a softening of the product. Studies of pectin changes, therefore, are important in investigations in which storage treatment alters the rate of ripening. That modification of pectic materials is a valuable criterion as a measure of metabolic difference in fruit is supported by the work of various investigators.

Haller (2) compared the rate of softening and pectic changes of several varieties of apples in cold storage and concluded that softening is apparently due to the conversion of insoluble pectic substances into the soluble form. More recently Smock and Allen (4) investigated pectic changes of various fruits under gas storage conditions. At a temperature of 45 degrees F normal soluble pectin increases in Yellow Newtown apples were retarded by storage in carbon dioxide. Van Doren (5) also concluded that coversion of protopectin to soluble pectin in apples is retarded by certain modified atmospheres and that this process continues at a greatly reduced rate for an extended period after the fruit is removed from storage.

In a study using modified atmospheres, Jonathan apples were stored under different carbon dioxide concentrations which altered the metabolism in the fruit of the various treatments. This was evidenced by differences in firmness, condition, ground color and flavor. Analyses of juice samples for soluble pectin were included in the investigation and the results of this phase of the work are herein reported.

METHODS

Jonathan apples uniform in size, color and maturity were selected on the optimum harvest date, October 2, 1941. The fruit was carefully handled, moved to the laboratory at once, wiped to remove spray residue and cold stored at 32 degrees F within a few hours after picking. The next day samples varying in number of apples from 57 to 69 were placed in 5-gallon, wide mouth glass jars, fitted with heavy metal, rubber gasket sealed covers held in place by screw clamps. Four such jars were connected in series with ⅛-inch copper tubes to a low pressure suction line in order to ventilate the samples slowly with the storage room atmosphere. This apparatus has been described in another publication (3). A flow-meter was used to regulate the movement of air through the set of jars. By this apparatus four different levels of carbon dioxide concentrations were obtained since each jar was ventilated with an atmosphere having a different carbon dioxide content. The carbon dioxide concentrations approximated 11, 9, 7, and 4 per cent. A series of four jars each was set up in each of two temperature rooms maintained at 31 to 32 degrees F and 35 to 36 degrees F. Comparable lots of fruit were packed in oiled paper and stored in apple boxes in the same storage rooms.

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Composite samples of apples consisting of comparable fractions of 15 apples were analyzed for soluble pectin at the time of removal from cold storage on April 1, and later the same procedure was performed on samples which had been held at room temperature (70 to 75 degrees F) for 2 weeks. The juice from these samples was expressed and filtered immediately through a Büchner funnel, using a filter pad consisting of a layer of filter paper plus a ⅜-inch pad of hardened acid-washed asbestos. The treatment removed suspended material and clarified the juice. Soluble pectin was determined on aliquot samples of clarified juice according to the method given by Carré and Haynes (1). The juice samples from apples of each storage treatment were analyzed in duplicate. The data obtained are averages of the determinations made in duplicate which checked closely.

RESULTS

The results obtained on the soluble pectin content of the various samples are given in Table I. These data indicate that storage in the controlled atmospheres inhibited to a marked degree the hydrolysis of protopectin to soluble pectin in the juice of the fruit. The soluble pectin content varied proportionately with the carbon dioxide concentration, except for one comparison. The higher the carbon dioxide level, the greater was the inhibiting effect. It is also significant that there was a residual effect of checking protopectin hydrolysis, as evidenced in the results for the samples left for 2 weeks in a warm room. These data clearly give evidence of greatly reduced soluble pectin formation and hence an indication of slower ripening in storage.

TABLE I—EFFECT OF DIFFERENT CARBON DIOXIDE CONCENTRATIONS AND STORAGE TEMPERATURES ON THE SOLUBLE PECTIN CONTENT OF JONATHAN APPLES (SOLUBLE PECTIN OF JUICE EXPRESSED AS PERCENTAGE OF CALCIUM PECTATE)

Percentage Carbon Dioxide	Apples Stored at 31 to 32 Degrees F		Apples Stored at 35 to 36 Degrees F	
	Upon Removal From Storage (April 1)	After 2 Weeks at Room Temperature (April 15)	Upon Removal From Storage (April 1)	After 2 Weeks at Room Temperature (April 15)
0 (Air storage)	.146	.309	.223	.366
3 to 4.5	.114	.233	.147	.260
5 to 7.5	.075	.178	.074	.194
8 to 10	.037	.145	.089	.175
10 to 12	.026	.134	.061	.156

A comparison between the samples stored at the two temperatures, in both air storage and in carbon dioxide, reveals a slightly further advanced condition of protopectin hydrolysis with the higher temperature. These results confirm other observations on the ripening of the fruit as measured by firmness, condition, ground color and flavor reported in another publication (3). Although ripening was retarded most at the 9 and 11 per cent levels of carbon dioxide, best results were obtained with the fruit stored near the 7 per cent concentration, as judged by flavor and freedom from brown heart.

CONCLUSIONS

The results of this investigation indicate that the storage of Jonathan apples in four carbon dioxide concentrations retarded the hydrolysis of protopectin to soluble pectin. The soluble pectin content varied proportionately with the carbon dioxide concentration and with storage temperatures of 32 degrees F and 36 degrees F.

A residual effect of inhibiting soluble pectin formation was evident, since proportionate differences between samples from different carbon dioxide atmospheres existed after the fruit was left at room temperature for 2 weeks. Under the same temperature, air-stored apples were consistently higher in soluble pectin than the fruit from any of the carbon dioxide atmospheres. The results confirm other observations that controlled atmosphere storage retards ripening.

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Effect of Carbon Dioxide and Temperature on the Decay of Sweet Cherries Under Simulated Transit Conditions

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SOME of the beneficial effects of carbon dioxide gas on the keeping quality of sweet cherries have been shown by the early studies of Brooks *et al.* (3) and by the more recent work of Brooks, Bratley, and McColloch (2), Gerhardt and Ryall (4), and Allen (1). All of the studies have emphasized the inhibitory effect of the gas on the development of mold and decay, but most of the tests have not dealt with specific kinds of decay, and in only one instance has an attempt been made to simulate conditions encountered in the commercial shipment of sweet cherries from the Pacific Coast States to eastern markets. These factors coupled with the lack of information relative to the effect of low concentrations of carbon dioxide on the development of cherry rots led to the present study. The kinds of decay under investigation were brown rot, the predominant type found in the cherry growing areas of California, and blue mold, one of the most common forms encountered in cherries shipped from the Pacific Northwest.

MATERIALS AND METHODS

The fungi used in the inoculation tests were *Sclerotinia fructicola* (Wint.) Rehm, isolated from a blighted cherry blossom from San Jose, Calif., and *Penicillium expansum* Link emend., Thom, obtained from a decaying apple. *S. laxa* also occurs on cherries in California but was not used in these experiments. In preparing the inoculum 10-day-old Petri dish cultures of these fungi on potato dextrose agar were used. By immersing the cultures in water and lightly scraping the surface of the agar, spore suspensions of the two fungi were secured.

Bing cherries of average commercial maturity were picked on July 6, 1941, and sorted, composited, and divided into three lots the following day. The fruit of two of the lots was punctured (one puncture per fruit) by means of a dissecting needle and inoculated by dipping in one of the spore suspensions, whereas that of the third remained unaltered. The cherries were then divided into 100-fruit samples and placed in paper bags preparatory to storing.

Immediately following preparation, the samples were stored at temperatures of 45, 36, and 31 degrees F for periods of 5 and 10 days. Large metal chambers with water-sealed lids were used for the lots held in atmospheres of carbon dioxide, and concentrations of this gas were maintained at 5, 10, and 20 per cent. The noninoculated lots were stored only in air and in 20 per cent gas. The relative humidities during the storage period varied from 85 per cent in air at 31 degrees to 93 per cent in gas storage at 36 and 45 degrees.

The fruit was removed and examined after intervals of 5 and 9 days, and again after a holding period of 2 days in air at 65 degrees F and 70 to 75 per cent relative humidity. Data were obtained on the percentage of decayed fruits, and the size of each of the rot areas in the inoculated lots was determined by measuring the diameter of the lesions on 20 cherries selected at random. Other decay characteristics recorded were sporulation and "leakiness", the latter term denoting the rupturing of the lesion with subsequent loss of juice. Isolations were made from all lesions on the noninoculated cherries and the isolates were identified as to genus.

RESULTS

The data pertaining to brown rot (*Sclerotinia fructicola*) are presented in Table I. No decay was evident in any of the lots after a storage period of 5 days, but after 2 additional days at 65 degrees F all lots showed infection. The fruit stored in carbon dioxide showed less decay than the checks held in air at the same temperature. The decay in the lot stored in air at 36 degrees was five times as great as

TABLE I—THE EFFECT OF CARBON DIOXIDE AND TEMPERATURE ON THE DECAY OF SWEET CHERRIES ARTIFICIALLY INOCULATED WITH *Sclerotinia fructicola*

CO_2 Gas (Per Cent)	At Withdrawal From Cold Storage				After 2 Additional Days in Air at 65 Degrees F			
	Decay (Per Cent)	Lesion Characteristics			Decay (Per Cent)	Lesion Characteristics		
		Diameter* (Mm)	Leakiness	Sporulation		Diameter* (Mm)	Leakiness	Sporulation
Storage Period 5 Days								
Temperature 31 Degrees F								
0	0.0	0.0	None	None	11.8	3.6	None	None
Temperature 36 Degrees F								
0	0.0	0.0	None	None	24.8	4.4	None	None
5	0.0	0.0	None	None	10.0	3.0	None	None
10	0.0	0.0	None	None	16.9	4.4	None	None
20	0.0	0.0	None	None	4.9	3.8	None	None
Temperature 45 Degrees F								
0	0.0	0.0	None	None	44.0	7.2	Slight	Slight
5	0.0	0.0	None	None	26.7	6.0	None	None
10	0.0	0.0	None	None	25.5	3.6	None	None
20	0.0	0.0	None	None	17.9	4.0	None	None
Storage Period 9 Days								
Temperature 31 Degrees F								
0	0.0	0.0	None	None	14.7	3.6	None	None
Temperature 36 Degrees F								
0	0.0	0.0	None	None	30.2	4.7	None	None
5	0.0	0.0	None	None	16.8	3.6	None	None
10	0.0	0.0	None	None	24.4	3.2	None	None
20	0.0	0.0	None	None	11.9	3.8	None	None
Temperature 45 Degrees F								
0	40.2	7.1	None	None	65.2	13.6	Moderate	Moderate
5	8.7	3.3	None	None	58.6	7.5	Slight	Slight
10	1.0	4.0	None	None	45.7	5.1	None	None
20	0.0	0.0	None	None	41.8	5.4	None	None

*Represents the mean diameter of the lesions on 20 fruits selected at random.

that in the sample held in 20 per cent gas at this temperature. At 45 degrees the inhibitory effect of carbon dioxide was not quite so pronounced as at 36 degrees, nevertheless it was considerable. Air storage at 31 degrees was more effective in retarding decay than 20 per cent gas at 45 degrees, but it was not so effective as 20 per cent gas at 36 degrees. Carbon dioxide reduced the size of the lesions at 45 degrees and prevented sporulation and leakiness.

Carbon dioxide effectively inhibited brown rot during a 9-day period at 45 degrees F. The lot held in air at this temperature showed nearly five times as much decay as the lot in 5 per cent carbon dioxide. No decay was evident in 20 per cent carbon dioxide. When the fruit was examined after 2 additional days at 65 degrees all of the lots treated with carbon dioxide during the initial storage period showed less decay than corresponding lots in air. There was a marked reduction in the size, sporulation and leakiness of the lesions on the cherries stored in carbon dioxide at 45 degrees, as compared with those on the lot stored in air at this temperature.

TABLE II—THE EFFECT OF CARBON DIOXIDE AND TEMPERATURE ON THE DECAY OF SWEET CHERRIES ARTIFICIALLY INOCULATED WITH *Penicillium expansum*

CO_2 Gas (Per Cent)	At Withdrawal From Cold Storage				After 2 Additional Days in Air at 65 Degrees F			
	Decay (Per Cent)	Lesion Characteristics			Decay (Per Cent)	Lesion Characteristics		
		Diameter* (Mm)	Leakiness	Sporulation		Diameter* (Mm)	Leakiness	Sporulation
				Storage Period 5 Days				
				Temperature 31 Degrees F				
0	0.0	0.0	None	None	73.3	5.9	Slight	Slight
				Temperature 36 Degrees F				
0	0.0	0.0	None	None	93.1	8.0	Slight	Slight
5	0.0	0.0	None	None	88.7	6.7	Slight	None
10	0.0	0.0	None	None	61.4	4.9	None	None
20	0.0	0.0	None	None	50.1	5.2	None	None
				Temperature 45 Degrees F				
0	72.0	4.0	None	None	100.0	13.0	Moderate	Dense
5	5.4	2.0	None	None	82.9	8.7	Slight	Slight
10	0.0	0.0	None	None	88.1	7.5	Slight	Slight
20	0.0	0.0	None	None	75.5	6.1	Slight	None
				Storage Period 9 Days				
				Temperature 31 Degrees F				
0	0.0	0.0	None	None	79.8	5.6	Slight	Slight
				Temperature 36 Degrees F				
0	59.0	4.1	None	None	95.7	11.3	Moderate	Moderate
5	6.5	2.2	None	None	84.7	7.6	Slight	Slight
10	0.0	0.0	None	None	79.0	7.7	Slight	None
20	0.0	0.0	None	None	81.6	6.4	Slight	None
				Temperature 45 Degrees F				
0	85.6	10.6	Moderate	Moderate	89.2	18.7	Severe	Dense
5	86.0	7.6	Slight	Slight	92.6	15.6	Severe	Dense
10	85.7	4.8	None	None	95.0	13.1	Moderate	Moderate
20	4.1	2.3	None	None	70.0	7.1	Slight	None

*Represents the mean diameter of the lesions on 20 fruits selected at random.

The results of the tests with blue mold (*Penicillium expansum*) are presented in Table II and Fig. 1. The effectiveness of 5 per cent carbon dioxide in checking decay at 45 degrees F during a 5-day period is clearly indicated. Air at 31 degrees F and 10 and 20 per cent carbon dioxide at 36 degrees gave complete blue mold control for 9 days, while 5 per cent carbon dioxide at 36 degrees and 20 per cent at 45 degrees were only slightly inferior.

When the fruit was examined 2 days after removal from storage the differences in percentage of decay were much less pronounced. However, at 45 degrees F carbon dioxide effected a marked reduction in the size, sporulation, and leakiness of the lesions. A temperature of 31 degrees had about the same inhibitory effect on decay as 20 per cent carbon dioxide at 36 and 45 degrees.

The fungistatic effect of carbon dioxide during storage is emphasized by the high percentages of decay encountered in all lots after a post-storage delay of 2 days in air at 65 degrees F. The data in Tables I and II and in Fig. 1 show the importance of the time of examination in determining decay control. They also indicate the desirability of using certain criteria in addition to the percentage of infected fruits in evaluating the inhibitory effect of carbon dioxide on fungus decay.

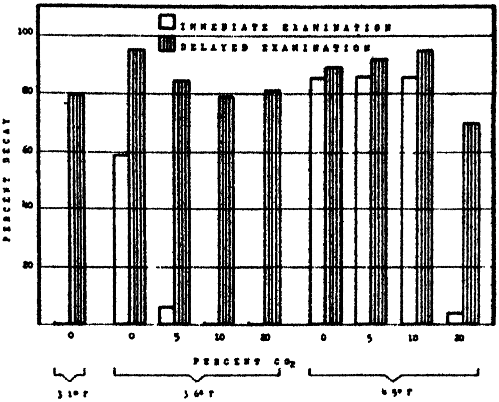

FIG. 1. The effect of carbon dioxide and temperature on the decay of sweet cherries artificially inoculated with *Penicillium expansum*. The immediate examination was made after a storage period of 9 days; the delayed examination after an additional 2 days in air at 65 degrees F.

Data for the noninoculated cherries are not presented in tabular form. In this series there was no significant amount of decay in any of the lots after 5 days' storage, or even after 2 additional days in air at 65 degrees F. When the fruit was stored 9 days and held 2 more days at 65 degrees, the lots held in air had two to three times as much decay as those in 20 per cent carbon dioxide at either 36 or 45 degrees. The fungi isolated from the lesions, in descending order of occurrence, are as follows: *Botrytis* sp., *Cladosporium* sp., *Pullularia (Dematium)* sp., *Hormodendron* sp., *Stemphylium* sp., *Penicillium* sp., and *Mucor* sp.

DISCUSSION AND CONCLUSIONS

The inhibition of brown rot and other kinds of decay, by carbon dioxide at concentrations within the range encountered in the commercial shipment of sweet cherries is clearly shown. It was also observed during investigations made by this Bureau on the transportation of sweet cherries to eastern markets. Those records, however, included only the percentage of unspecified decay and were not based on fruit inoculated under controlled conditions.

Shippers of sweet cherries from districts in California where brown rot is severe also report that cherries shipped in atmospheres of carbon dioxide arrived at eastern markets in better condition than fruit shipped in cars without this supplement to refrigeration.

The inter-relationship of temperature and concentration of carbon dioxide in inhibiting decay is emphasized. A gas concentration effective in controlling decay at 36 degrees F may be totally ineffective at 45 degrees. With brown rot, air storage at 31 degrees was superior to 20 per cent gas at 45 degrees, but slightly inferior to a 20 per cent concentration at 36 dergees. The results suggest that if the temperature in refrigerator cars should be maintained close to 31 degrees F the decay of sweet cherries in transit could be effectively controlled without the addition of carbon dioxide. The recent development of forced-air circulation in refrigerator cars makes this attainment entirely within the realm of possibility.

The fungistatic effect of carbon dioxide is evident from the data obtained by examining the fruit at the time of removal from gas storage and again after 2 days in air at 65 degrees F. The importance of the time of examination and the criteria employed to evaluate control thus become apparent.

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A Colorimetric Method for CO_2 Determination in Respiration Studies[1]

By L. L. CLAYPOOL and R. M. KEEFER, *University of California, Davis, Calif.*

A RAPID method for the determination of CO_2 given off by respiring plant materials is desirable where many tests are to be made at the same time. The methods now most generally used which retain CO_2 in an alkaline solution require the measurement of relatively large amounts of CO_2 in order to give accuracy. This results in respiration tests of one to several hours duration and necessitates taking an average of the CO_2 evolved in that period. Where the respiration rate of the material being tested is undergoing rapid and continuous change, tests of short duration have obvious advantages.

A method suitable for tests of short duration and where small amounts of CO_2 are involved is that of equilibrating the gas containing CO_2 with a dilute sodium bicarbonate solution and measuring the resulting pH. This is adaptable only to determining the amount of CO_2 evolved by respiring materials and does not replace the method of Magness and Diehl (1) where a measure of O_2 consumption is also desired. The pH can be measured by means of a glass electrode (2) or a colorimeter (3). Winzler and Baumberger (3) have used a photocell colorimeter to determine the per cent CO_2 in gases from about 1.0 to 8.0 per cent CO_2 and found that the accuracy was much better than with the ordinary commercial glass electrode which reads to 0.02 pH units. It was the object of this investigation to see if this method could be applied to respiration studies where gases of 0.01 to 1 per cent CO_2 are involved. The method was found to be applicable and is quite rapid. About 40 CO_2 readings may be made by one person in an hour while with the absorption type of apparatus one person can run only about 20 to 25 tests a day. In both of these cases it is assumed that the respiration chambers were already in operation.

DESCRIPTION OF PROCEDURE AND APPARATUS FOR RESPIRATION STUDIES

Briefly, the method of analysis consists in passing a known volume of CO_2 free air over a weighed portion of plant material to be tested and then equilibrating this air sample with a dilute solution of sodium bicarbonate containing an appropriate indicator. The solution is then placed in the Evelyn Colorimeter and the per cent transmission is determined. By comparing this per cent transmission with a previously established curve of per cent CO_2 vs per cent transmission, the per cent of CO_2 in the gas may be obtained.

It is not essential to use CO_2 free air if the per cent CO_2 in the compressed air remains constant. However, by doing so no correction is necessary. For the colorimetric method to be properly applied, the

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[1] Joint contribution from the Divisions of Pomology and Chemistry.

The writers wish to acknowledge the valuable assistance of Mr. L. R. McKinnon for his help particularly in designing the scrubbing tower.

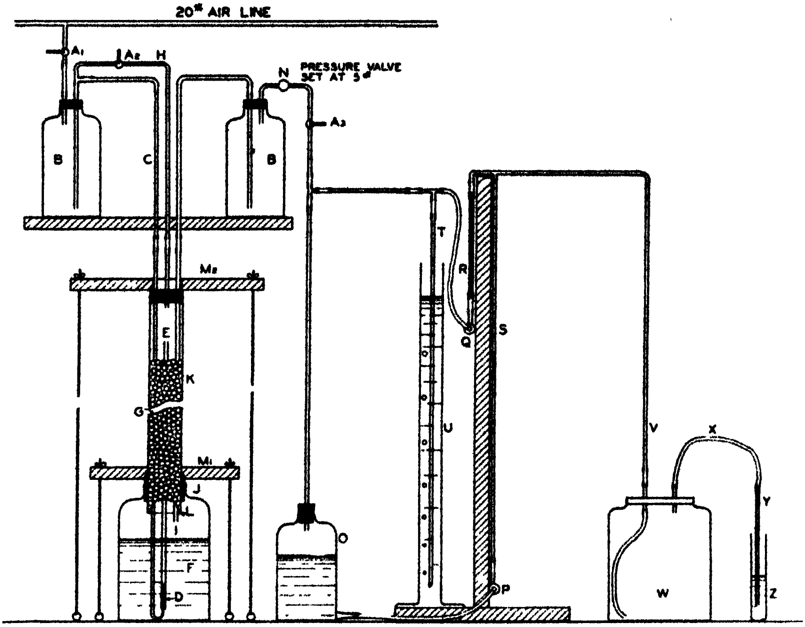

FIG. 1. Schematic drawing of scrubbing tower and flowmeter.

air flow through the respiration chambers must be constant. For this purpose flowmeters of high accuracy are needed.

Fig. 1 is a schematic drawing of the air flow through a scrubbing tower for removal of CO_2 and into the flowmeters where it is measured before passing over the fruit and into the indicator solution.

Scrubbing Tower:—This tower (K) is set up between two pressure regulators in order that changes in the pressure of compressed air will not affect the air flow to the respiration chambers. The air from the compressor is reduced to about 20 pounds prior to reaching the scrubbing tower. Heavy walled trap bottles (B) of sufficient size to hold most of the alkali in jar F are placed in the air lines on either side of the scrubbing tower to protect the lines from alkali in case of trouble. The scrubbing tower (K) is made of Pyrex tubing about 7 centimeters in diameter and 30 inches long. A wire screen (L) is fitted onto the base to hold pebbles or glass beads (G). The lower end of the column is fitted into a rubber stopper (J) which in turn is fitted to a 4-liter jar having a mouth of about 8.2 centimeters diameter. It is essential to clamp (M_1) the lower connection to the table to prevent the rubber stopper from blowing out. It is also necessary to clamp (M_2) the top of the tower to the table so that it will not be lifted from the alkali jar by the air pressure.

The alkali used in absorbing CO_2 need not be more than a 15 to 20 per cent solution since a sodium carbonate precipitate will clog up the air lift pump before all of the alkali in a solution of this concentration is used up, necessitating renewal of the solution. In our experience one charging of the scrubbing tower with 3 liters of alkaline solution will remove the CO_2 from enough air to operate 50 respiration chambers for 1 month with an air flow of about 100 cubic centimeters each per minute.

An air lift pump to keep the alkali from jar (F) continually spraying (E) over the absorbing surfaces in the tower is made by leading the incoming air through a tube (C) to the bottom of the alkali bottle where the belled out portion of another tube (D) is placed over the inverted point of the air line so that it carries both air and alkali to the top of the tower (E), thereby wetting the pebbles or glass beads.

If more air is needed than is easily passed by the air lift pump a needle valve or pinch clamp (A_2) in tube (H) from the air line to the top of the tower can be opened to give a greater supply. After the air has the CO_2 removed by passing over the wet alkaline surface it enters tube (I) and returns to the compressed air line flowing toward the respiration chambers. A regulator (N) reduces the air pressure to about 5 pounds. Tube (I) and possibly tube (C) could come directly into jar (F) without passing through the tower if this were desired.

Respirometer:—After the air has passed through the regulator (N) which reduces it to low pressure it is carried to constant temperature rooms where respiration studies are conducted.

Needle valve (A_3) is opened slightly. This causes a static pressure to develop on the system. Leveling jar (O) acts as the high pressure arm to all of the flowmeters attached to manifold (P) and causes solution to rise in tube (S). The height of the rise is dependent upon the difference in pressure on either side of the capillary portion (R) of the flowmeter connected onto manifold (Q) and can readily be adjusted by changing the depth of immersion of tube (T) in the barostat tower (U). Once adjusted, the flowmeters will remain nearly constant even with a considerable variation in the amount of excess air released through the barostat. The barostat tower should be at least 1½ inches in diameter. The air passing through each flowmeter is led through a tube (V) to the bottom of a respiration chamber (W). By removing the air through a tube (X) at the top of the chamber good mixing is assured. This tube is kept open until a gas analysis is to be made at which time a capillary tube (Y) is attached so that air may be bubbled through the indicator solution in the colorimeter tube (Z).

Our flowmeters are made up on plywood boards in series of 11, 10 of which are used for respiration and one as a blank. Each flowmeter must of course be calibrated for the pressure difference under which it is operated. The greater the pressure difference for a given flow, the more accurately can the flow be adjusted. We have set upon 20 inches as a convenient head, being the difference in height between the liquid in jar (O) and tube (S). As long as the flow from respiration chamber (X) is not obstructed all of the flowmeters in the series will remain under the same pressure difference by the one adjustment of tube (T) in the barostat tower, even though the flowmeters vary 50 per cent in their capacity. As soon as the capillary tube (Y) is placed in the line and partly immersed in the indicator solution, the resultant back pressure will reduce the rate of flow. An adjustment again of tube

(T) in the barostat tower will give a gross adjustment. For final leveling of all lof the flowmeters it will then be necessary to make slight adjustments of the depth of immersion of the capillary tube (Y) in the indicator solution. These adjustments are very simple and rapid. Capillary tube (Y) is used to give an even air flow through the indicator solution and to prevent contamination that would result were the rubber tube immersed in the indicator solution. Capillary tube (Y) and the indicator solution cause a back pressure of 3 to 4 inches of water which is considered too small to justify an air volume correction in ordinary studies.

More or fewer flowmeters can be operated from the same leveling bottle. The amount of air flow desired will of course determine the size and length of capillary in the flowmeter. For most tests capillary tubing of 0.2 to 0.3 millimeters in size is desirable. It is considered best to maintain an air flow sufficiently rapid to keep the CO_2 to 0.5 per cent or less in order that its accumulation will not influence metabolic processes in the fruit. For small flows thermometer tubing may be required. It is recommended that the respiration chamber used be only large enough to accommodate the material under test, thereby reducing to a minimum any lag in showing changes in respiration rate. Fig. 2 is a photograph of the respirometer in operation.

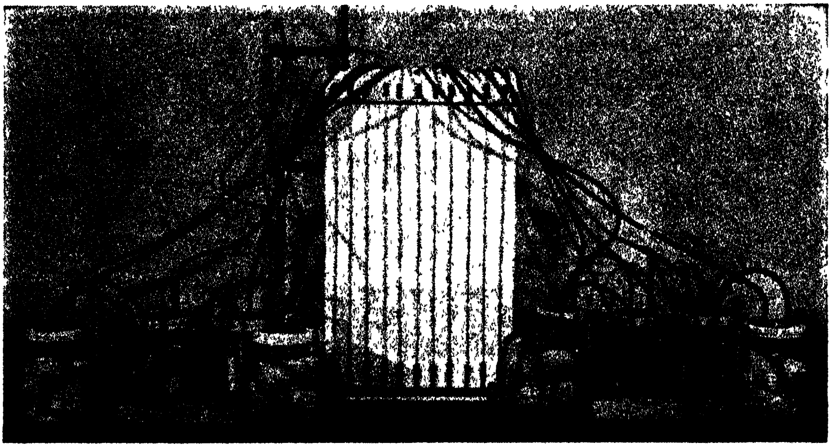

FIG. 2. Respirometer in operation.

DISCUSSION OF THEORY

Since this method of determining the per cent of CO_2 in a gas is dependent upon the pH of a sodium bicarbonate solution with which the gas is in equilibrium, the gas can contain no substances other than CO_2 which produce an acidic or a basic reaction when dissolved in water.

The following equilibria are involved when a gas containing CO_2 is in equilibrium with water:

$$CO_2(_g) \rightleftharpoons CO_2(_{aq}) \qquad K_x = \frac{(CO_2)_{aq}}{P_{CO_2}} \tag{1}$$

$$CO_2(_{aq}) + H_2O \rightleftharpoons H_2CO_3 \qquad K_y = \frac{(H_2CO_3)}{(H_2O)\,(CO_2)_{aq}} \tag{2}$$

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \qquad K_1 = \frac{(H^+)\,(HCO_3^-)}{(H_2CO_3)} \tag{3}$$

If the value of H_2CO_3 from equation 2 and the value of $(CO_2)_{aq}$ from equation 1 are substituted in equation 3, equation 4 is obtained:

$$K_1 = \frac{(H^+)\,(HCO_3^-)}{K_xK_y\,(H_2O)\,P_{CO_2}} \tag{4}$$

If enough HCO_3^- is added to the solution prior to equilibrating the solution with the gas containing CO_2 so that the amount of HCO_3^- furnished as a result of H_2CO_3 ionizing is negligible compared to the amount of HCO_3^- originally added, than (HCO_3^-) is a constant and equation 4 will reduce to

$$-\log P_{CO_2} = k\,pH \tag{5}$$

where k is a constant and is equal to $\log \frac{K_xK_y\,(H_2O)\,K_1}{(HCO_3^-)}$.

Different indicators have different pH ranges through which they change color. In the central section of these pH ranges the change in color as measured by the colorimeter reading is proportional to the pH of the solution. This is shown in Fig. 3 for phenol red indicator. Therefore using equation 5 and this same pH range a straight line relationship should be obtained between log P_{CO_2} and the colorimeter reading.

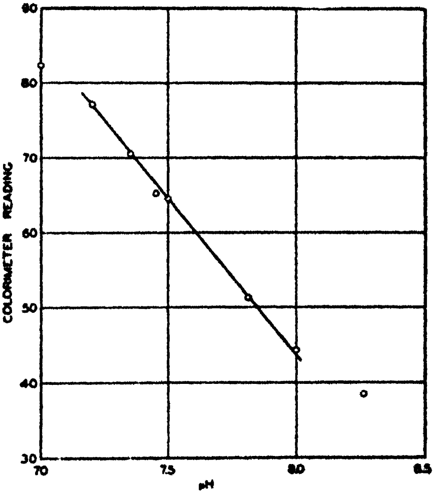

FIG. 3. Relationship between pH and colorimeter reading of phenol red indicator solution.

METHOD

For the low range of per cent CO_2 (0.01 to 1 per cent) indicators were chosen which change color at about a pH of 7. Two indicators were used, namely bromthymol blue and phenol red. An Evelyn colorimeter was used to determine the transmission of the indicator solutions. A 620 filter with transmission limits of 595 to 660 millimicrons was used for bromthymol blue which has a maximum absorption at 617 millimicrons. A 565 filter with transmission limits of 550 to 585 millimicrons was used for the phenol red which has a maximum absorption at 558 millimicrons.

The following tables gives the composition of the indicator solution tested:

Indicator	Concentration of Indicator Per Cent $\times 104 = 10^4$	$NaHCO_3$ Concentratin N $\times 103 = 10^3$
Bromthymol blue	5	1
Phenol red 1	2	1
Phenol red 2	2	2.5
Phenol red 3	2	5

The above indicator solutions were prepared by dilution from stock solutions which were made up to be 100 times the final strength wanted. In order to maintain uniformity in the amount of indicator in the diluted solutions each dilute solution is tested as follows: 50 cubic centimeters of the dilute indicator solution was pipetted into a 100 cubic centimeter volumetric flask; 5 cubic centimeters of 0.1N NaOH was added to completely convert the indicator to its basic form and then the solution was diluted to 100 cubic centimeters with distilled water. Portions of the solution were then placed in colorimeter tubes and read in the colorimeter using appropriate filters. The bromthymol blue solution read 55.0 with 620 filter and the phenol red solution read 52.0 with a 565 filter. If the values differed from these, the original solution was adjusted so that when diluted as above these values would be obtained.

Gases of varying known CO_2 content were prepared from a cylinder of 10 per cent CO_2 and CO_2 free air measuring each by means of flowmeters. Equilibrium is established quite rapidly when a gas containing CO_2 is passed through an aqueous solution except when the per cent of CO_2 in the gas approximates zero. In order to determine how much time should be allowed for equilibrium the 0.0002 per cent phenol red solution containing 0.0025N HCO_3- was first equilibrated with CO_2 free air,

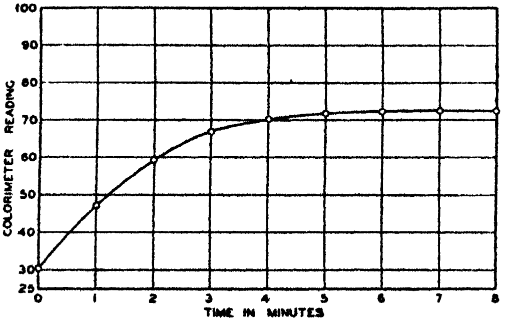

FIG. 4. Time required to equilibrate indicator solution at 65 degrees F.

then 0.5 per cent CO_2 was passed through the solution and readings were taken at frequent intervals. The results are shown in Fig. 4. After 6 minutes the readings were constant. All data presented here are based on duplicate tests of 10 minutes each.

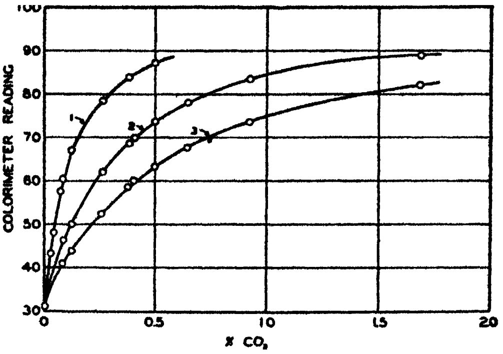

Fig. 5. Colorimeter reading in relation to per cent CO_2 at 65 degrees F. Curve 1, Phenol red indicator 1; curve 2, Phenol red indicator 2; curve 3, Bromthymol blue indicator.

The colorimeter tubes provided with the Evelyn colorimeter were used for all tests. About 20 cubic centimeters of solution was used in each tube. Immediately after equilibrating with the CO_2 gas sample the tubes were sealed with rubber stoppers and then read in the colorimeter.

Fig. 5 shows the relation between colorimeter reading and the per cent of CO_2 for the bromthymol blue indicator (curve 3) and for phenol red. The effect of changing the HCO_3- concentration is shown in curves 1 and 2 of Fig. 5. This is also shown in Fig. 6 where the colorimeter reading is plotted against the log per cent CO_2 for phenol red indicator in 0.001N HCO_3-, in 0.0025N HCO_3- and in 0.005N HCO_3-.

It may be seen that the central portion of each curve is a straight

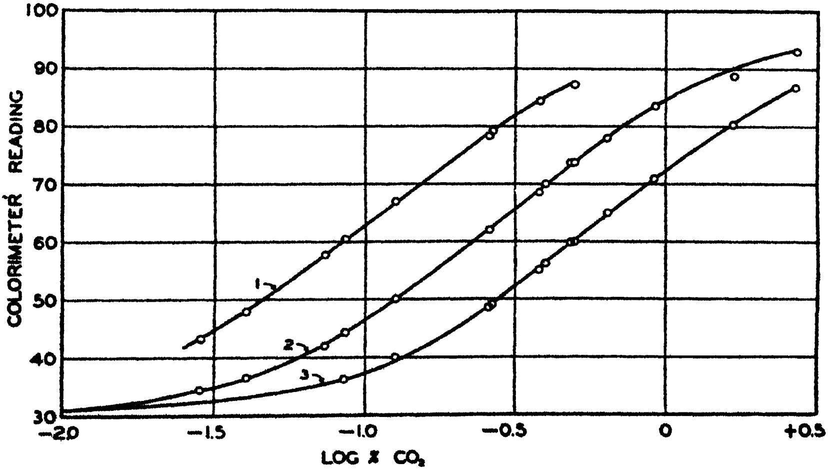

Fig. 6. Colorimeter reading in relation to log per cent CO_2 at 65 degrees F. Curve 1, Phenol red indicator 1; curve 2, Phenol red indicator 2; curve 3, Phenol red indicator 3.

line in agreement with theory. However, after the whole curve is experimentally established, it may be used over a much larger range than the straight line section.

In Table I, column 2, the range of per cent CO_2 for which each indicator solution gives a straight line relationship is given. Column 3 in Table I gives the slope of each straight line.

TABLE I—RANGE AND SLOPE OF CURVE

$NaHCO_3$ Concentration	Range of Per Cent CO_2	Slope Units/log Per Cent CO_2	Temperature (Degrees F)
	Bromthymol Blue		
0.001	.40 to 1.2	38.3	80
0.001	.25 to 1.0	38.0	65
0.001	.20 to 0.9	40.2	45
	Phenol Red		
0.0025	.25 to 1.0	39.4	80
0.005	.40 to 1.2	39.0	80
0.001	.04 to .25	38.4	65
0.0025	.25 to .80	40.7	65
0.005	.30 to .80	43.6	65
0.0025	.11 to .50	39.0	45
0.005	.20 to .70	43.8	45

From the slopes recorded in Table I it is possible to obtain the accuracy of the method. It is possible to reproduce readings to 0.25 units colorimeter reading. Using a slope of 40 units/log per cent CO_2 would mean that 1 unit would represent 0.025 units in log per cent CO_2 and that .25 units would represent 0.006 units in log per cent CO_2. Thus for 0.5 per cent CO_2 assuming an error of 0.25 units in the reading there would be a 3.5 per cent error in the per cent of CO_2. As readings can be reproduced to 0.25 units the error is probably somewhat smaller than 3.5 per cent.

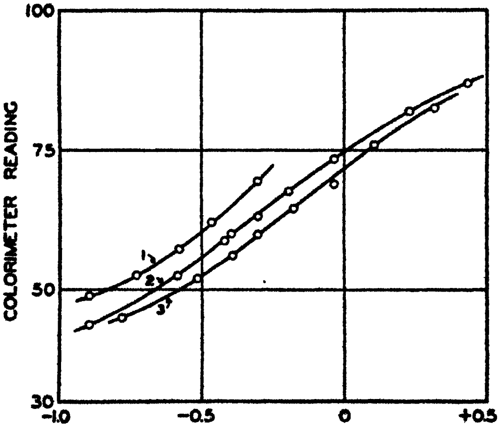

FIG. 7. Effect of temperature on colorimeter—log per cent CO_2 curves of bromthymol blue indicator solutions. Curve 1, 45 degrees F; curve 2, 65 degrees F; curve 3, 80 degrees F.

The colorimetric method is adapted largely to constant temperature conditions since temperature has such a marked effect on the equilibrium between the partial pressure of CO_2 in the air and amount of CO_2 in its various forms in solution. In Fig. 7 the effect of temperature is shown. Curve 1 is for 45 degrees F, curve 2 is for 65 degrees F, and curve 3 is for 80 degrees F. However, the method may be adapted to changing temperatures if the indicator solutions are kept at a desired constant temperature while being brought to equilibrium with the air from the respiration chamber. The colorimeter and indicator solution being measured in it need not be at the same temperature, but some means should be used to keep the indicator at a constant temperature prior to its being read.

It is essential that good technique be adopted in preventing contamination of the indicator solutions in the colorimeter tubes. Clean capillary bubblers (Y) will do much to assure this. The colorimeter tubes should be cleaned quite often in cleaning solution and rechecked against the standard tube used for comparison. The indicator solutions may be used for several determinations if carefully handled. The number can best be determined by each operator since both evaporation and contamination will affect this. Under our conditions it was felt desirable to renew the indicator solution after about six tests.

A large number of respiration determinations were made by the colorimetric method in 1941. The colorimeter reading was used to calculate the respiration rate according to the following formula:

$$\frac{\text{Per cent } CO_2 \times \text{cubic centimeters of air per hour} \times \text{milligrams } CO_2 \text{ per cubic centimeters } CO_2}{\text{kilograms fruit}} = \text{milligrams } CO_2 \text{ per kilogram fruit per hour}$$

The colorimeter reading establishes the per cent CO_2 in the air coming from the respiration chamber. The milligrams CO_2 per cubic centimeter CO_2 is dependent upon temperature and atmospheric pressure. Fig. 8 shows the respiration rates of one lot of Delicious apples and one lot of 133–6 tomatoes.

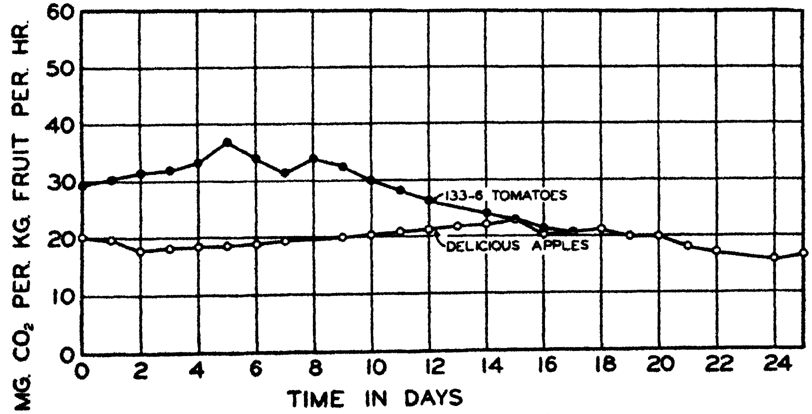

FIG. 8. Respiration rates of apples and tomatoes.

The mechanical devices and the colorimetric method described here have been devised especially for respiration studies, but with modifications might apply to photosynthetic tests. For this latter purpose a different choice of indicator and buffer concentrations might be desirable.

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The Influence of One Lot of Apple Fruits on Another

By R. M. Smock, *Cornell University, Ithaca, N. Y.*

THE stimulatory effect of ethylene on the respiration process in apples and pears has been known for a good many years. More recently the work of Gane (2) and Nelson (6) has shown that apples and pears evolve ethylene themselves. Nelson (6) has shown that the peak in ethylene production follows the respiratory peak of McIntosh apples by about 4 days at a temperature of 20 degrees C. Biale and Shepherd (1) have recently demonstrated that blue mold of lemons generated enough ethylene to stimulate the ripening rate of green lemons. Other fungi tested were not able to generate sufficient ethylene to have this effect.

This study was initiated to test the magnitude of the effect of a rapidly ripening lot of apples which were presumably generating considerable ethylene (4 and 6) on a second less mature lot of fruit. The possibility of blue mold of apples (*Penicillium expansum*) generating sufficient ethylene to stimulate the ripening of pre-climacteric apples was also studied.

METHODS

Respiration was measured on approximately 1½ kilogram samples of apples. Carbon dioxide free air was passed over the fruit at the rate of 28 liters per hour. Absorption of carbon dioxide coming from the fruit was accomplished in towers containing frittered glass plates to produce very small bubbles. Tenth normal potassium hydroxide was used for absorption. The carbon dioxide was precipitated out with barium chloride and titration with tenth normal hydrochloric acid followed. The respiration chambers were immersed in a constant temperature water bath. The air stream was brought to the desired temperature by passing it through copper coils immersed in the water bath. Temperatures of 80 degrees and 74 degrees F were used.

The technique of Biale and Shepherd (2) was followed more or less closely in examining the effect of one lot of fruit on another. After the normal respiration rates for the various lots were determined, treatments were initiated. The air stream passing over treated lots was moved from chambers containing the ripe fruit or rotted fruits for 18 hours. Then flushing was allowed for at least 1 hour before the respiration determinations were made. Daily treatments continued for periods of time as indicated in the text.

Pre-climacteric (i.e. prior to the respiratory "hump") fruit was used for the respiration measurements except in the case of Yellow Newtowns.

DUCHESS OF OLDENBURG

The normal respiration rates of three lots of Duchess apples were determined for 2 days and then treatments were started after the respiration determination of the second day. One lot was treated with the vapors coming from two McIntosh apples. These McIntosh were almost a year old but were in good condition, having been stored in controlled atmosphere storage. A second lot was treated with two

McIntosh apples that were half decayed with *Penicillium expansum.* The treatments were continued for 8 days at 80 degrees F.

Fig. 1 indicates that within 24 hours after the initiation of the treatment, the vapors from the ripe McIntosh stimulated the respiration of the Duchess apples. The respiratory maximum was passed 3 days sooner with this treatment than with the control. Vapors from the half-rotten McIntosh stimulated ripening, but not nearly so markedly as did the normal McIntosh. The experiment with Wealthy indicates that this effect was undoubtedly due to the normal tissue of the fruits and not the rotten portions.

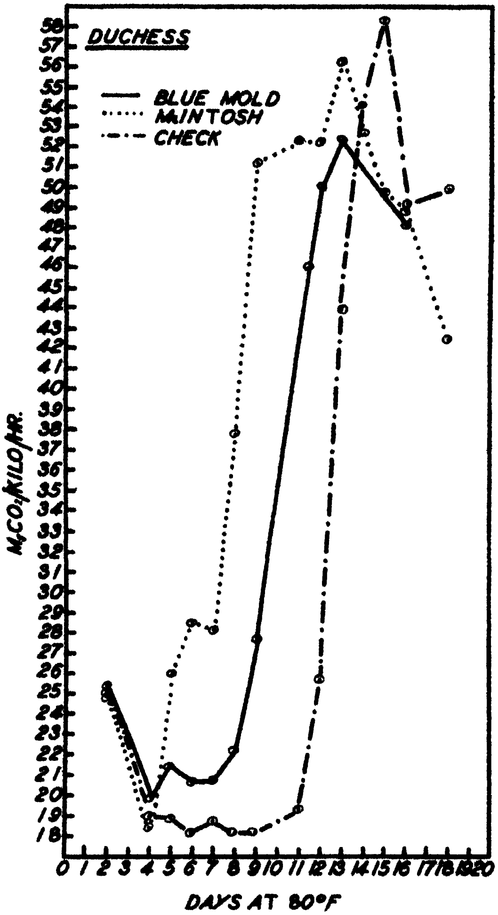

FIG. 1. The effect of emanations from full ripe McIntosh apples and from full ripe McIntosh partially decayed with blue mold on the respiration of Duchess apples (treatment started second day).

WEALTHY

In the experiment with Wealthy, the McIntosh apples used were full eating ripe, similar to those used on Duchess. The fruits affected with blue mold, however, were completely rotten. No healthy tissue remained. Treatments stopped after 7 days. Three McIntosh fruits were used in each case.

It may be seen from Fig. 2 that emanations from the ripe McIntosh caused an immediate stimulus in the respiration of the Wealthy. The respiratory maximum was reached, as a result of this treatment, 4 days before that of the control. It may be seen that the effect continued after the treatments were stopped. The completely rotten fruit had no stimulatory effect on the respiration of the Wealthy. There seemed to be no significant difference between the control lot and those treated with rotten McIntosh.

In another phase of this experiment one lot of Wealthy was treated with the vapors emanating from full ripe Yellow Transparent. Not only did these Wealthy fruits ripen faster than the untreated, but they had an injury similar to that described by Kidd and West (5).

McINTOSH

In this experiment 1941 McIntosh were treated with 1-year-old McIntosh similar to those used on Duchess and also eating-ripe 1941 Early McIntosh. Treatments were begun on the second day. The treatment with ripe Early McIntosh was stopped after 3 days and with 1-year-old McIntosh after 4 days. Three Early McIntosh and three 1-year-old McIntosh fruits were used.

The vapors emanating from the Early McIntosh apples markedly stimulated the ripening rate of these pre-climacteric McIntosh apples. The respiratory peak was reached in 4 days with the Early McIntosh treatment and had not been reached on the control after 12 days. Although the data is not shown in Fig. 3, the control McIntosh began their normal respiratory rise on the 12th day. The McIntosh treated with Early McIntosh had lost 4.3 pounds more in firmness as measured by a pressure tester than the control lot.

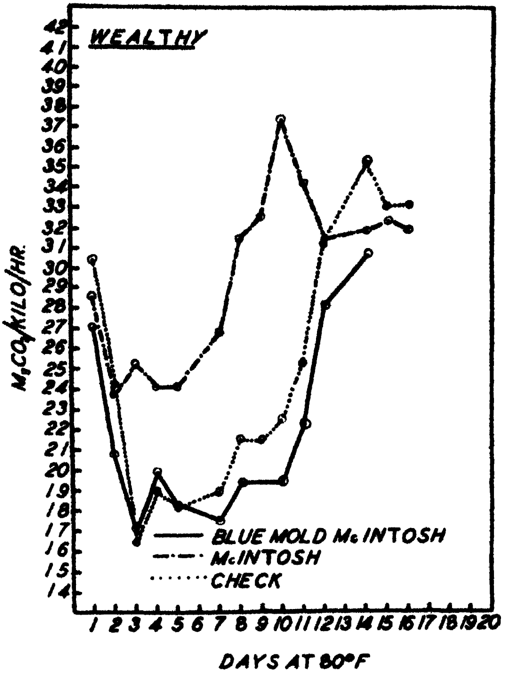

FIG. 2. The effect of emanations from full ripe McIntosh apples and from completely rotten (blue mold) McIntosh on the respiration of Wealthy apples (treatments started second day).

The vapors coming from the 1-year-old McIntosh caused a stimulation of the respiratory rate of the 1941 McIntosh but the effect was not nearly so marked as with the Early McIntosh. This was presumably due to the fact that they were not evolving as much ethylene.

YELLOW NEWTOWN

Yellow Newtown apples were treated with emanations from three apples each of Yellow Newtown and rapidly ripening McIntosh. The Yellow Newtown emanations were employed as an additional check or control. They were apples similar to those in the respiration chamber. Treatments were begun after the second day's respiration run was made and continued until the end of the experiment.

It may seem from Fig. 4 that the emanations of ripe McIntosh had no influence on the respiration rate of these Yellow Newtown apples.

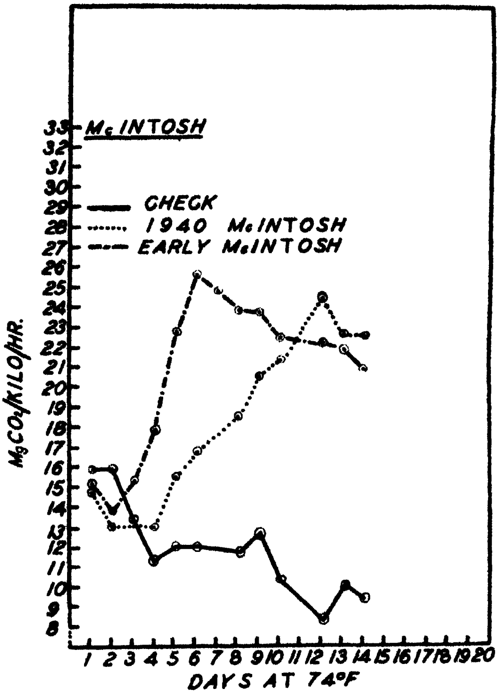

FIG. 3. The effect of emanations from 1-year-old McIntosh and from ripe Early McIntosh apples on the respiration of McIntosh apples (treatments started second day).

The respiration curves indicate that the Newtowns were in a post-climacteric condition when picked. The Newtowns had a pressure test of 20.4 pounds and a ground color of 2½ to 3 at the time of picking and had evidently passed the climacteric on the tree. When the experiment was discontinued the fruits were full yellow and slightly past the eating ripe condition.

There are two possible explanations why no effect of the McIntosh emanations were apparent on the Newtowns. One is that this variety was not influenced by the quantities of ethylene evolved from the three ripe McIntosh fruits. A more logical and likely explanation is that the Newtowns were in a post-climacteric state when treated and hence were unaffected. Hansen and Hartman (3) have shown that treatments with ethylene after the respiratory peak has been passed were ineffective in stimulating the respiration rate of pears.

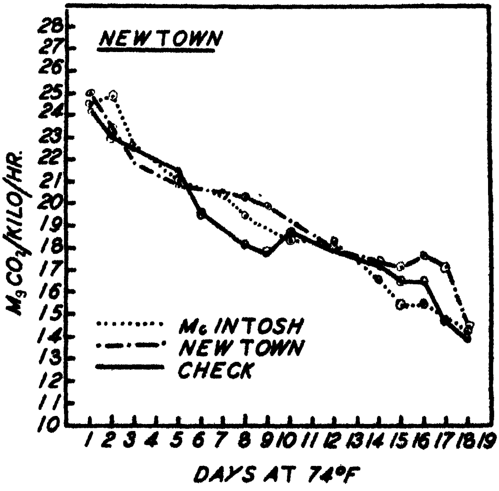

FIG. 4. The effect of emanations from ripe McIntosh and from Yellow Newtown apples on the respiration of Yellow Newtown apples (treatment started second day).

DISCUSSION

The question is often raised by cold storage operators as to the desirability of storing different varieties together in the same room. It is conceivable that a lot of apples which is evolving considerable quantities of ethylene might have some effect on the ripening rate of a second lot in the pre-climacteric state. Such a situation would be most likely to prevail when circulation and ventilation were rather poor in the storage room.

While this study has shown that rapidly ripening lots of apples may markedly influence pre-climacteric apples, there are several points that need further clarification. One question that remains to be answered is whether or not this ethylene effect is as marked at cold storage temperatures as was evident at the high temperatures used in this study. This point is being examined during the 1941–42 season. A second question is whether or not there is sufficient ventilation in the typical apple storage room to remove undesirable concentrations of naturally evolved ethylene. A third point is to determine of what practical magnitude this effect is in ordinary cold storage practice where some apples are put into storage in a pre-climacteric and some in a post-climacteric condition.

In addition to this ethylene effect, there is at least one other possible effect one lot of apples may have on another in storage. This is the possible stimulation of scald by a variety or lot of apples which is rapidly evolving volatiles. A preliminary study of this point in 1940–41 indicated that in controlled atmosphere storage where ventilation is naturally very limited this factor might be of some importance. When Wealthy apples were stored alone in controlled atmosphere storage, they developed no scald. When they were stored with McIntosh apples under similar storage conditions, they developed 54 per cent of severe scald. How much of a factor this variety effect may be in cold storage practice is being studied during the 1941–42 season.

SUMMARY

The emanations of ripe apples markedly stimulated the respiration rate of pre-climacteric Duchess, Wealthy, and McIntosh apples. In one case the ripe apples were of the same variety as that being tested. Definite ethylene injury was apparent as a result of passing the vapors from ripe Yellow Transparent apples over pre-climacteric Wealthy fruits. The emanations of ripe McIntosh apples had no effect on the respiration of post-climacteric Yellow Newtown fruits.

Penicillium expansum did not seem to generate sufficient ethylene to stimulate the ripening of Duchess or Wealthy apples.

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Carbon Dioxide Storage for Yellow Newtown Apples

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CARBON DIOXIDE ATMOSPHERE WITH DIFFERENT PROPORTIONS OF OXYGEN

THE first report upon the storing of Yellow Newtown apples in atmospheres of carbon dioxide was made in 1934 (1). Additional tests were conducted in 1935 and 1936 in which the fruit was held in 5 and 10 per cent of carbon dioxide with a corresponding reduction in oxygen. After 12 weeks at 45 degrees F in 10 per cent carbon dioxide and 10 to 11 per cent oxygen, the fruit was of similar color and firmness to that stored in air at 32 degrees F (2). Moreover, the flesh was entirely free of internal browning, which is usually severe at the lower temperature.

An approximate one to one ratio of carbon dioxide and of oxygen, such as would normally occur through natural respiration of the fruit, appeared to be satisfactory. However, tests with Bartlett pears (3) have shown that 10 per cent carbon dioxide with only 5 per cent oxygen present (or even 5 per cent carbon dioxide with only 2.5 per cent of oxygen) was even more effective in retarding coloring and softening. Similar trials were conducted in 1938–39 and in 1939–40 with Yellow Newtown apples.

In the first set of trials comparable lots of fruit were held at 32, 36, and 40 degrees F in large glass containers to which was pumped from pressure tanks atmospheres containing:

CO_2 — 10 per cent; O_2 — 15 per cent
CO_2 — 10 per cent; O_2 — 5 per cent
CO_2 — 0 per cent; O_2 — 2 per cent
CO_2 — 0 per cent; O_2 — 21 per cent

On April 17 the fruit was removed from storage. In each case where the oxygen content was reduced, the fruit was materially more firm and of less color than that held in air. Table I. Where the oxygen was reduced to 2 per cent, and even in the absence of carbon dioxide, the apples held at 32 degrees and at 36 degrees were of slightly less color than those of the other lots. At 40 degrees, however, an atmosphere of 5 per cent oxygen and 10 per cent carbon dioxide was more effective in retarding development of ground color. Fruit stored in a low oxygen atmosphere without carbon dioxide did not ripen with such good appearance or flavor as that stored in a combination of 5 per cent of oxygen and 10 per cent of carbon dioxide.

In the second series of trials at 45 degrees F, the following atmospheres were employed:

Lot 1. 10 per cent — CO_2; 10.0 per cent — O_2
Lot 2. 10 per cent — CO_2; 5.0 per cent — O_2
Lot 3. 5 per cent — CO_2; 2.5 per cent — O_2
Lot 4. 0 per cent — CO_2; 2.5 per cent — O_2
Lot 5. 0 per cent — CO_2; 21.0 per cent — O_2 (air)
Lot 6. 0 per cent — CO_2; 21.0 per cent — O_2 (air at 36 degrees)
Lot 7. 0 per cent — CO_2; 21.0 per cent — O_2 (air at 32 degrees)

TABLE I—Carbon Dioxide Storage of Yellow Newtown Apples (April 17, 1939)

Atmosphere		Storage Temperature (Degrees F)	Color*	Firmness	General External Appearance	When Removed From Storage			Condition—Dessert Quality
						Browning (Per Cent)			
CO₂ (Per Cent)	O₂ (Per Cent)					Slight	Moderate	Bad	
10	15	32	2½ to 3	18.7	Good	0	30	70	Unmarketable
		36	2½ to 3	17.0	Good	20	20	60	Unmarketable
		40	3½ to 4	16.2	Good	0	0	0	Fair, moderately juicy, ripe
10	5	32	2 to 3	19.5	Good	0	0	100	Unmarketable
		36	2 to 3	19.1	Good	20	30	50	Unmarketable
		40	Mostly 3	17.2	Good	0	0	0	Fair, flavor fair, scarcely ripe
0	2	32	2– to 2+	19.8	Mostly good	40	20	30	Unmarketable
		36	2 to 2½	17.5	Mostly good	60	0	0	Fair, flavor rather poor
		40	2 to 3½	16.9	Mostly good	0	0	0	Fair, flavor rather poor
0	21	32	3 to 3½	12.5	Good	30	30	40	Unmarketable, overripe and tasteless
		36	Mostly 3½	11.8	Good	60	20	0	Poor, overripe, dry
		40	4	13.1†	Unmarketable	0	0	0	Poor, overripe, mealy

*Color figures refer to color chart of the California State Department of Agriculture.

†Pressure test high on account of shrivelling; fruit in open box; 100 per cent scald; 30 per cent decay when removed from storage, April 17th.

After 8 weeks the fruit held in air at 45 degrees F was showing a definite change in color and at the end of 12 weeks had, on account of scald, reached its commercial storage limit. Little color change had occurred in any of the lots stored in carbon dioxide. By the middle of February when the air sample was yellow and showing severe scald and considerable Alternaria and Cladosporium rot, lot 4 (Co_2 0 per cent — O_2 2.5 per cent) was turning from light green to yellowish green and the fruit was showing some slight scald. Lot 1 (CO_2 10 per cent — O_2 10 per cent) was just "breaking color," whereas lots 2 and 3 (CO_2 10 per cent — O_2 5.0 per cent and CO_2 5.0 per cent — O_2 2.5 per cent) were essentially of the same appearance as when stored.

Table II gives the color and condition of each lot after 24 weeks and after 31 weeks and further illustrates the effects of reduced oxygen in retarding coloring and softening. This retarding effect of reduced oxygen in the presence of carbon dioxide is also reflected in the number of days required for the fruit to ripen after removal from storage and the number of days it was considered marketable.

In lot 4, where the fruit was held in the same low oxygen atmosphere as lot 3 (O_2 2.5 per cent) but in the absence of carbon dioxide, the results were not successful. Although coloring was retarded nearly as much as in lot 1 (CO_2 10 per cent — O_2 10 per cent), the fruit was more mellow, showed much more scald, was of lower dessert quality and in reality was unmarketable after 24 weeks.

On May 3, after 31 weeks at 45 degrees, the different lots of fruit held in carbon dioxide atmospheres were of similar color and firmness but required longer to ripen and were marketable longer than fruit held in air at 36 degrees. In these tests internal browning failed to develop at this temperature but did develop to some extent at 32 degrees F. The apples in lots 2 and 3 held in 10 and 5 per cent carbon dioxide respectively at 45 degrees F were of similar appearance and slightly more firm than the comparable fruit held in 32 degrees air, a storage temperature usually quite unsuitable for the Yellow Newtown grown in the Pajaro Valley of California.

In general, an atmosphere of 5 to 10 per cent of carbon dioxide and an oxygen content of only 2.5 to 5.0 per cent gave the best results. This is in agreement with results secured with Bartlett pears (3), and the conclusions drawn by Smock (4) when he worked with McIntosh and Cortland apples.

COMMERCIAL STORAGE TRIALS

What is thought to be the first and most extensive commercial carbon dioxide storage trial with apples in this country is the one carried out in 1938 at Watsonville, California, in cooperation with the National Ice and Cold Storage Company and with 12 individual growers who supplied 4,000 boxes of Yellow Newtown apples for the test. This fruit was stored unwrapped with the boxes stacked closely together in a room which would just accommodate them. In another room of much larger capacity in the same plant, comparable lots were held for comparison. The test was designed so that the smaller room would be held at a temperature of 42 degrees F and contain a concentration of 10

TABLE II—CARBON DIOXIDE STORAGE OF YELLOW NEWTOWN APPLES (1939–40)
(Fruit Harvested September 26, 1939 — Color Green to Light Green — Firmness 21.6 Pounds)

Storage Atmosphere		When Removed From Storage										Days to Ripen at 70 Degrees F	Quality When Ripe	Total Days Marketable
		Firmness (Pounds)	Color (Per Cent)					General Condition	Scald (Per Cent)	Decay (Per Cent)	Browning (Per Cent)			
CO_2	O_2		Gr.	Lt. Gr.	Y. Gr.	Gr. Y.	Yel.							
March 14, 1940—After 24 Weeks at 45 Degrees F														
10.0	10.0	17.0	—	50	—	50	—	Mostly good	25 slight	0	0	4	Good	30
10.0	5.0	19.3	40	45	15	—	—	Good—excellent	0	0	0	7	Good	40
5.0	2.5	17.2	40	45	15	—	—	Excellent	0	0	0	7	Good	40
0.0	2.5	15.2	—	50	—	50	—	Poor	50 slight, 25 moderate	0	0	1	Fair	None
0.0	21.0	13.5‡	—	—	—	—	100	Unmarketable	100	20	0	0§	Poor	0
0.0	21.0*	13.4	—	50	50	50	—	Good	0	0	0	0	Good	20
May 3, 1940—After 31 Weeks at 45 Degrees F														
10.0	10.0	13.9	—	30	—	60	10	Poor—Fair	70 slight	0	0	0 to 5	Fair	3 to 10
10.0	5.0	17.4	—	70	30	—	—	Good	10 slight	0	0	10	Fair	15
5.0	2.5	16.4	—	90	10	—	—	Good	10 slight	0	0	10 to 12	Fair	15
0.0	2.5	14.2	—	25	50	—	25	Unmarketable	30 bad	0	0	0	Very poor	0
0.0	21.0	—	—	—	—	50	50	Unmarketable	75 bad	25	0	0	None	0
0.0	21.0*	14.4‡	—	30	—	70	—	Poor—fair	35 slight	0	0	0	Fair§	3
0.0	21.0†	15.0	—	70	30	—	—	Poor	0	0	50 slight	0	Fair	15

*Air at 36° F.
†Air at 32° F.
‡Firmness slightly too high on account of shriveling.
§Overripe.

per cent carbon dioxide. The temperature in the larger or regular air-storage room was maintained at 36 to 37 degrees F.

No special preparation was given the "gas" storage room except to put in a false door and to stop all places where leaks were anticipated. The desired concentration of gas was to be maintained through respiration of the fruit or, if necessary, supplemented by carbon dioxide gas supplied from pressure tanks. The color and firmness of the fruit was recorded at the time it was placed in storage and preliminary inspections were made on February 16 and April 4, 1939. On May 15, fruit was removed from the room, observed and tested, then held under normal outside temperatures for 2 weeks for final observation.

It was soon evident that without unloading the room and making the walls, ceiling and floor impervious to carbon dioxide that the desired concentration could not be maintained without supplying very large quantities of carbon dioxide. During the first month only 1 to 2 per cent carbon dioxide was present, which in reality was slightly less than the amount found in the air room containing a much larger amount of fruit. After this period, however, a general average of 6 per cent carbon dioxide was maintained. Comparisons, therefore, had to be made between comparable lots of fruit held in 6 per cent carbon dioxide only after the first month and those held in another room, which on account of large volume of fruit and lack of ventilation, contained carbon dioxide in considerable amount. Despite the fact atmospheres were not under control, rather definite results were secured.

RESULTS

Color Changes:—On February 16, 1939 only slight color changes over those when harvested were noticeable. The fruit stored in each of the two rooms was very similar in appearance. In 3 samples out of 12, there was slightly less color development in the fruit stored in carbon dioxide. This same similarity of color between the lots in the gas and the lots in the air rooms was observed at the two later inspections and indicates that a concentration of approximately 6 per cent carbon dioxide and a temperature of 42 degrees F retards color development to just about the same extent as 36 degrees F air.

Firmness Changes and Texture:—Softening of the fruit could be measured more exactly. The average firmness of the 12 lots when harvested was 19.5 pounds as measured by a pressure tester with a 7/16-inch plunger point. On February 16 after 18 weeks, the average firmness was 16.3 pounds. Since the concentration of carbon dioxide in the gas room during the first few weeks of storage was no higher than in the air room, there were no consistent differences in firmness at the time of the first inspection.

Texture of the flesh was determined by cutting and sampling. In most instances the fruit stored in carbon dioxide at 42 degrees was considered slightly more crisp than that of the corresponding lots from the air room held at 36 degrees F. The relative humidity in the two rooms was essentially the same, varying between 85 and 90 per cent.

After an additional 6 weeks, or on April 4, firmness of the different lots was again measured, Table III. Eight lots held in carbon dioxide were firmer than those held in air, two were the same and two averaged

TABLE III—COLOR, FIRMNESS AND PERCENTAGE OF INTERNAL BROWNING OF YELLOW NEWTOWN APPLES (STORED AT 42 DEGREES F IN 6 PER CENT CARBON DIOXIDE AND IN AIR AT 36 DEGREES F)

Lot No.	Color of Fruit			Firmness of Fruit			Browning (Per Cent)*	
	When Stored	Out of Storage		When Stored	Out of Storage		Out of Storage	
		CO_2	Air		CO_2	Air	42 Degrees F (CO_2 Room)	36 Degrees F (Air Room)
				First Inspection—February 16, 1939				
1 to 12	2 –3	2 –3½	2½–3½	19.5	16.3	16.3	0	25
				Second Inspection—April 4, 1939				
1.	2 –2½	2½–3½	2½–4	20.6	16.2	14.5	0	70
2.	2½–3	3 –4	3 –	20.6	15.7	14.5	0	50
3.	2 –2½	2 –2½	2 –2½	18.9	14.1	14.1	0	50
4.	2 –3	2½–3	3 –3½	18.3	14.4	13.8	0	90
5.	2 –4	3 –4	3 –4	18.9	13.8	11.9	0	80
6.	2 –3	3½	3½	19.8	15.2	13.6	0	20
7.	2 –3	2½–4	3 –4	21.6	15.6	15.2	0	40
8.	2 –3	2½–4	2½–4	19.0	14.1	14.9	0	0
9.	2 –2½	2½	2½–3	18.2	13.7	13.7	0	20
10.	2½–3	3 –4	3½	19.7	14.2	14.9	0	0
11.	2½	2½–3	2½–3	20.0	16.0	15.6	0	20
12.	2 –3	2½–4	2½–4	18.8	14.7	13.0	0	80
Average	———	———	———	19.5	14.8	14.1	0	43
				Third Inspection—May 15, 1939				
1.	2 –2½	2½–3½	2½–4	20.6	14.6	12.4	0	100
2.	2½–3	3 –4	3 –4	20.6	14.4	12.8	0	50
3.	2 –2½	2 –3	2 –3	18.9	12.9	11.9	0	10
4.	2 –3	2½–3½	3 –4	18.3	13.6	12.0	0	100
5.	2 –4	3 –4	3 –4	18.9	12.5	10.4	0	100
6.	2 –3	3 –4	3 –4	19.8	14.2	12.7	0	10
7.	2 –3	2½–4	4	21.6	14.5	13.6	0	30
8.	2 –3	3 –4	3 –4	19.0	13.4	12.8	0	30
9.	2 –2½	2½–3	3 –4	18.2	11.9	11.0	0	50
10.	2½–3	3 –3½	3½–4	19.7	12.2	12.8	0	0
11.	2½	2½–3	3 –3½	20.0	14.4	13.4	0	40
12.	2 –3	2½–4	2½–4	18.8	12.6	10.5	0	60
Average	———	———	———	19.5	13.4	12.2	0	48

*On April 4 most browning was only "trace" to "slight" and would not effect the market value of the fruit greatly. On May 15, however, its severity had increased.

slightly softer. The average firmness of those lots held in carbon dioxide was 14.8 pounds; in air, 14.1 pounds. The gas-stored fruit was somewhat more firm and juicy and less sweet than the more mellow, riper samples stored in air.

On May 15 after 30 weeks of storage, 11 samples out of the 12 stored in gas were from 1 to 2 pounds firmer than those stored in air, the average difference being 1.2 pounds. At this time, the fruit stored at 36 degrees in air was past good eating quality. The better lots were lacking in juice and crispness and were insipid. In most lots the flesh was showing a sufficient development of internal browning to give it a "dead" appearance. The gas-stored samples were generally crisp, juicy, and moderately sweet; the flesh was devoid of any browning.

Internal Browning:—No evidence has been secured to indicate that carbon dioxide atmospheres per se control or retard internal browning to which most of the Yellow Newtown apples grown in the Pajaro Valley of California are susceptible. However, since this trouble does not develop at a storage temperature of 40 degrees F or above, carbon dioxide atmospheres permit the use of these temperatures with no increase in ripening over that which occurs at the more usual storage temperature employed for apples.

Scald:—Apples are more susceptible to scald at 40 degrees than at 36 degrees or lower. Practically all California Newtowns are stored loose and scald development on loose apples is usually less serious than on those wrapped (either oiled or plain wraps) and packed. In this test at 42 degrees a slight amount of incipient scald was present in four lots of fruit. Previous trials, in which apples were held in carbon dioxide atmospheres, have given results indicating that at temperatures of 40 to 45 degrees F carbon dioxide retards scald.

Life of Fruit Subsequent to Storage:—Final observation of the above lots of fruit was made May 29, 1939, after they had been shipped from storage and exposed to San Francisco atmospheres for a period of 2 weeks. At this time color differences still persisted in certain lots of fruits stored in carbon dioxide and in air, and in most comparisons the former was less mellow, more juicy and of better flavor. All fruit had reached or was nearing the end of its commercial life. The comparative condition of the different lots, however, may be summarized as follows:

	Fruit stored in	
	CO_2 at 42 degrees	Air at 36 degrees
Samples marketable 10 days....	10	2
Samples marketable 3 to 5 days..	2	4
Samples unmarketable	0	6
Average percentage of internal browning	0	50
Average percentage of decay....	11	20

Conclusions:—Although carbon dioxide concentrations in the gas storage room were no greater during the first month of storage than in the air room, and subsequently averaged only 6 per cent, the fruit held in the gas chamber at 42 degrees F kept in better condition than comparable fruit held under general commercial conditions at 36 degrees F, and this difference persisted after the fruit was removed from storage and was exposed for sale.

PRE-STORAGE TREATMENTS WITH CARBON DIOXIDE

Owing to the necessary expense of preparing cold storage rooms for holding satisfactory concentrations of carbon dioxide obtained from fruit respiration, trials were made to determine if exposure to relatively high concentrations of carbon dioxide for 15 days would (a) be effective in retarding coloring and softening of fruit subsequently stored in air at 36 degrees (the present commercial storage temperature for California Yellow Newtowns), or (b) whether such treatments carried out at 40 degrees F would in any way prevent the development of internal browning in fruit stored at 32 degrees.

Fruit with a 2 to 2½ color[1] and a firmness of 20.6 pounds was secured on October 4, 1939, from an orchard at Watsonville, California, and immediately brought to Davis where it was divided into four lots and held for 15 days at a temperature of 40 degrees F in the following atmospheres:

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[1] Color chart, California State Department of Agriculture.

Lot 1. CO_2 — 35 per cent; O_2 — 5.0 per cent
Lot 2. CO_2 — 20 per cent; O_2 — 2.5 per cent
Lot 3. CO_2 — 15 per cent; O_2 — 2.5 per cent
Lot 4. CO_2 — 0 per cent; O_2 — 21.0 per cent

Following this preliminary treatment each lot was again divided, half being stored at 36 degrees and half at 32 degrees in air. Inspections and tests were made after 18 and after 28 weeks. Beyond each of these periods differences in the color of fruit given the different preliminary treatments were too slight to be significant.

In the fruit stored at 32 degrees differences of 1.4 to 2.0 pounds were found in the firmness between that treated with 35 per cent carbon dioxide and that which was not treated. After 28 weeks, however, there was no consistency in the effects secured from the different carbon dioxide concentrations. No differences in firmness were found after 18 weeks in the fruit stored at 36 degrees and only slight differences after 28 weeks (Table IV).

TABLE IV—INFLUENCE OF PRELIMINARY CARBON DIOXIDE TREATMENTS FOR 15 DAYS AT 40 DEGREES F BEFORE STORAGE

Lot No. and Treatment	Firmness After 18 Weeks (Pounds)		Firmness After 28 Weeks (Pounds)	
	At 32 Degress	At 36 Degress	At 32 Degrees	At 36 Degrees
1. 35 per cent CO_2	19.3	18.1	15.2	13.0
2. 20 per cent CO_2	18.9	18.1	15.9	12.4
3. 15 per cent CO_2	18.7	18.1	13.6	12.7
4. Air	17.1	17.9	13.8	12.4

Thus while the preliminary treatments appear to have had some slight effect and are in general agreement with the results of Brooks (5) in whose experiments fruit was treated 2 days and then ripened immediately, it appears that where the fruit is to be held for long periods in storage that even a 2 weeks treatment in high concentrations of carbon dioxide is of relatively little importance.

Both at time of removal from storage and 15 days later observations were made on the development of internal browning. Browning was materially more severe in fruit stored at 32 degrees than at 36 degrees but the preliminary carbon dioxide treatments were without effect.

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Relation of Sexual Reproduction to Development of Horticultural Plants I. General Effects of Flower and Fruit Production[1]

By A. E. MURNEEK and S. H. WITTWER, *University of Missouri, Columbia, Mo.*

THAT there is a close relationship between sexual reproduction and plant development is generally acknowledged. The prevailing interest on the subject, however, seems to be focused largely in one direction, *viz.*, on the type of vegetative growth that may be conducive or detrimental to reproduction, usually in its connection with plant nutrition. This restricted point of view may be excusable to a certain extent if one considers only such annual plants whose life span terminates after fruit or seed production. Most perennials and many annuals with a continuous type of growth, however, have recurrent periods of flowering and fruiting. Their life does not end with but is altered markedly by reproduction. The reproductive organs and associated tissues exert a conspicuous physiological control on their metabolism and subsequent development. Reproduction having proceeded at a maximum, the plants may become periodically or permanently restricted in vegetation (slow terminal growth, few shoots, small leaves) or reproduction (few flower buds, flower and bud abortion) or both (1). This post reproductive stage of retarded development is usually followed by recovery and repetition of the cycle, consisting of rapid growth, leading to reproduction and inhibited development, which is followed by recovery of growth. The number of cycles and the "intensity" of each phase of the cycle depend upon several factors, which cannot be enumerated here.

The interesting feature in this sequence of events is that these changes are to a large extent independent of the external environment, but directly related to flower and fruit production (2). It is conspicuously "internal".

SOME EXPERIMENTAL EVIDENCE

The present paper deals with the general effects of flower and fruit production on subsequent growth, behavior, and gross chemical composition of some horticultural plants. The material used for this study consisted of several well known flowers and vegetables, as is indicated in the accompanying tables. They were grown in the usual way in fertile soil in pots or in benches. The experimental treatments consisted of daily or periodic disbudding (when buds of convenient size), defloration (at anthesis), or defruiting (a few days after fertilization). Records were taken of the total number of visible buds (flowers) produced, the dry weights, and the total accumulation of nitrogen and carbohydrates in various parts of the plants.

Information presented in Table I shows that the number of flowers (buds) produced was far greater, usually several-fold, when the plants

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TABLE I—EFFECTS OF DISBUDDING, DEFLORATION, AND DEFRUITING ON TOTAL NUMBER OF VISIBLE FLOWERS (BUDS) PRODUCED (NUMBER PER 10 PLANTS)

Kind of Plant and Treatment	Daisy (Dwarf)	Marigold (Dwarf)	Cosmos (Orange Flare)	Dill	Pepper (Windsor)
Disbudded........	362	326	5410	4080	1370
Deflorated........	—	—	1177	—	870
Defruited........	—	—	—	—	637
Control (fruiting)..	180	77	500	737	173

Kind of Plant and Treatment	Bean (Stringless Green Pod)	Tomato (Marglobe)	Rudbeckia (Bicolor)	Rudbeckia (Bicolor Superba)
Disbudded........	—	561	262	276
Deflorated........	470	655	102	136
Defruited	315	540	46	—
Control (fruiting)..	90	327	38	58

were disbudded. This increase was proportionally smaller under defloration and still less under defruiting, which would seem to indicate that it was here a matter of increased conservation of foods when the reproductive organs were removed at the earlier stages. Undoubtedly this was a very important, probably the chief but not the only, factor as will be seen forthwith.

The reproductive "capacity" of a continuously developing plant is not determined solely by the genetic constitution and the environment,

TABLE II—TOTAL DRY WEIGHTS OF VEGETATIVE AND REPRODUCTIVE PARTS (IN GRAMS PER 10 PLANTS)

Kind of Plant and Treatment	Whole Plants	Shoots, Roots and Leaves	Buds (Removed)	Flowers (Removed)	Fruit (Removed)	Fruit and Flowers (Control Plants)
Daisy						
Disbudded........	92.3	87.5	4.8	—	—	—
Controls (fruiting) .	98.0	83.0	—	—	—	15.0
Marigold						
Disbudded	33.3	28.0	5.3	—	—	—
Controls (fruiting)..	29.1	16.0	—	—	—	13.1
Cosmos						
Disbudded	246.6	198.5	48.1	—	—	—
Deflorated	138.5	96.2	—	42.3	—	—
Controls (fruiting)..	57.9	53.2	—	—	—	4.7
Bean						
Deflorated.........	285.9	280.7	—	5.2	—	—
Defruited........	296.5	290.5	—	—	6.0	—
Controls (fruiting)..	299.5	97.5	—	—	—	202.0
Tomato						
Disbudded........	959.0	948.0	11.0	—	—	—
Deflorated.........	1201.4	1174.7	—	26.7	—	—
Defruited........	1233.9	1159.6	—	—	74.3	—
Controls (fruiting)..	1021.1	608.4	—	—	—	412.7
Rudbeckia						
Disbudded.........	73.6	63.0	10.6	—	—	—
Deflorated.........	95.8	71.4	—	24.4	—	—
Defruited..........	77.4	58.6	—	—	18.8	—
Controls (fruiting)..	69.6	50.4	—	—	—	19.2

but to a large extent by the preceding reproductive activity. Two or three cycles of flowers were often produced on the fruiting (control) plants without any change in the nutrient supply. But once the plants had produced fruit heavily, the succeeding flowers would not set and sometimes even the flower buds abscissed in various stages of development. How many aborted before they became visible is unknown, but their number undoubtedly was very large. Accompanying this, there was commonly a premature senescence of the older leaves and curtailment of growth of the shoots and stems. A few cases were observed (cosmos, daisy, and marigold) where highly reproductive branches or whole plants died, though the nutrient supply was ample as evidenced by luxurient growth of adjoining non-fruiting plants. Frequent inhibition of younger fruit by older could be noted (tomato).

In Table II are presented the total dry weights of various portions of the plants. Considering the more concentrated food materials, including fat, in the reproductive organs (seeds), the control or fruiting plants evidently produced about as much dry matter as did the treated ones. The apparent inefficiency of cosmos was undoubtedly due to greater inhibition in development by the first group of flowers and fruit, with a consequent reduction (death) of foliage and even some twigs.

In reference to the total production of dry matter, the most intriguing feature is that many of the disbudded, deflorated and defruited plants (cosmos, tomatoes, and rudbeckia) excelled in this respect. And, what is probably more significant, they almost invariably accumulated more nitrogen and synthesized more carbohydrates than the fruiting (control) plants (Tables III and IV). Continuous observation of the plants and the above records made it very suggestive that a physiological stimulation occurred during certain stages of sexual reproduction. There was evident a very conspicuous retarding effect by

TABLE III—TOTAL NITROGEN IN VEGETATIVE AND REPRODUCTIVE PARTS (IN GRAMS PER 10 PLANTS)

Kind of Plant and Treatment	Whole Plant	Shoots, Roots and Leaves	Buds (Removed)	Flowers (Removed)	Fruit (Removed)	Fruit and Flowers (Control Plants)
			Pepper			
Disbudded..........	(4.296)	4.296	—			
Deflorated..........	(5.300)	5.300		—		
Defruited..........	(4.454)	4.454			—	
Controls (fruiting)..	3.814	2.396				1.418
			Bean			
Deflorated..........	7.162	6.990		0.172		
Defruited..........	8.430	8.132			0.298	
Controls (fruiting)..	2.380	1.536				0.844
			Tomato			
Disbudded..........	9.620	9.132	0.488			
Deflorated..........	13.348	12.356		0.992		
Defruited..........	13.528	11.270			2.258	
Controls (fruiting)..	12.224	5.706				6.518
			Rudbeckia			
Disbudded..........	0.894	0.610	0.284			
Deflorated..........	1.046	0.592		0.454		
Defruited..........	0.812	0.442			0.370	
Controls (fruiting)..	0.688	0.348				0.340

TABLE IV—SUGAR AND STARCH, AS GLUCOSE, IN VEGETATIVE AND REPRODUCTIVE PARTS (GRAMS PER 10 PLANTS)

Kind of Plant and Treatment	Whole Plant	Shoots, Roots and Leaves	Buds (Removed)	Flowers (Removed)	Fruit (Removed)	Fruit and Flowers (Control Plants)
			Pepper			
Disbudded	(10.02)	10.02	—			
Deflorated	(10.42)	10.42		—		
Defruited	(11.50)	11.50			—	
Controls (fruiting)	25.69	6.41				19.28
			Bean			
Deflorated	43.45	42.51		0.94		
Defruited	33.77	33.15			0.62	
Controls (fruiting)	37.27	5.54				31.73
			Tomato			
Disbudded	185.32	184.60	0.72			
Deflorated	285.83	283.43		2.40		
Defruited	287.84	275.17			12.67	
Controls (fruiting)	226.40	115.31				111.09
			Rudbeckia			
Disbudded	5.14	4.52	0.62			
Deflorated	6.20	4.11		2.09		
Defruited	4.85	3.62			1.23	
Controls (fruiting)	2.48	1.58				0.90

the developing fruit and seed, exhibited by all fruiting (control) plants. This is in agreement with previously reported results (1, 2, and 3).

We have investigated in some detail the "stimulating" phase(s) of sexual reproduction and have found that it probably consists of two stages, which may be correlated with flower development. The one occurs soon after fertilization, may be quite readily subjected to experimental analysis, and has been studied by us (4). The second probably appears at synapsis, is more difficult to establish, but is being determined at present. During both stages (if there be only two) catalytic substances of the nature of hormones probably are secreted, which influence the metabolism of a plant bearing flowers and fruit.

We are not convinced that the very evident retardation in growth in presence of developing fruits and seeds is due entirely to starvation of various parts of the plant because of diversion of food to the fruits and seeds. It is very probable that this may be caused by the release of an inhibitor(s) of some kind by the embryos and associated tissues, which may inhibit to various extents and degrees other parts of the plant. This may explain the usual recovery, without a change in the external environment, as soon as the fruit and seeds have matured.

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Relation of Sexual Reproduction to Development of Horticultural Plants II. Physiological Influence of Fertilization (Gametic Union)[1]

By S. H. WITTWER and A. E. MURNEEK, *University of Missouri, Columbia, Mo.*

IT IS common knowledge among horticulturists that developing embryos exert a profound influence upon the fruit, but it is less generally known that such an influence may extend beyond the limits of the fruit, and reach to the farthest vegetative extremities. This fact, that the fertilization of the flowers results in a growth stimulation beyond the fruit, was first discovered and emphasized by one of the writers (2), while working with the tomato. Subsequently, Dearborn (1) observed a similar effect in the cucumber. Further observations on the general affects of flower and fruit development in the bean, pepper, and rudbeckia are presented by Murneek and Wittwer (3). Results herein submitted likewise substantiate the hypothesis that gametic union does exert a significant influence upon vegetative development, fruit size, and yield.

EXPERIMENTS WITH CUCUMBERS

The Longfellow variety of cucumber was grown during the spring in rich soil in 10-inch pots. Two plants were raised in each pot and trained to strings attached to wires in the top of the greenhouse. The plants developed quite normally and were kept free from disease or insect pests. The experimental treatment was as follows:

1. Control; all plants allowed to fruit normally; fruits produced by pollination and subsequent fertilization.
2. Plants allowed to fruit normally except that 2 to 3 days after pollination 0.5 per cent indole butyric acid in lanolin was applied to the very young fruit.
3. Plants induced to form parthenocarpic fruits by application of 0.5 per cent indole butyric acid to the stigmas.
4. Flowers were pollinated and fertilization occurred, but young fruits were removed as soon as signs of development were apparent.
5. Flowers pollinated and fertilized and in addition 0.5 per cent indole butyric acid was applied when the stigma dried; young fruits removed as in 4.
6. Treatment as in 3, but parthenocarpic fruit removed as in 4.
7. Flower buds removed at or just prior to anthesis.
8. Flower buds removed as soon as they could be separated from the plant without injury.

Table I presents the dry weights, in grams, of the various plant constituents along with the total amount of dry matter produced, and the heights in centimeters attained in each group.

The effects of gametic union are quite evident in these results. In examining group 4, it will be observed that the amount of dry matter

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TABLE I—RESULTS WITH CUCUMBERS

Group and Treatment	Leaves (Grams)	Stems (Grams)	Fruit (Grams)	Flowers and Buds (Grams)	Total (Grams)	Final Heights (Cm)
1. Control (pollinated, fertilized)	10.66	3.22	12.14	0.42	26.44	157.2
2. Control—same as 1 +.5 per cent β-indole butyric acid	10.93	3.50	10.21	0.26	24.90	152.0
3. Parthenocarpic fruits produced	14.67	5.33	10.34	0.56	30.90	181.2
4. Defruited (pollinated, fertilized)	20.20	7.80	1.73	0.64	30.37	192.5
5. Defruited as 4, +.5 per cent β-indole butyric acid	19.73	7.11	2.10	0.68	29.62	177.3
6. Defruited. Parthenocarpic fruits removed	16.98	6.10	1.45	0.56	25.09	150.9
7. Deflorated	16.51	6.31	——	3.00	25.82	152.2
8. Disbudded	31.93	8.60	——	0.375	40.905	168.3

produced is significantly greater than that in group 6, yet fruit was formed and removed in both groups, the only difference between the two being that the fruits produced in group 4 contained fertilized embryos, whereas those in group 6 did not. Is it possible that gametic union can exert such a conspicuous influence on vegetative growth? It should be noted also that group 5, in which gametic union also occurred, compares very favorably with group 4; likewise the dry weights of plants in group 7 agree very closely to those in group 6, fertilization, of course, not occurring in either class. The very significant increase in vegetative extension as a result of fertilization provides additional evidence for the stimulatory affect of this process. The results obtained from tentative chemical analyses agree with, and in some instances even emphasize, those results for the total amount of dry matter produced.

EXPERIMENTS WITH PEPPERS

Pepper plants, variety King of the North, were grown in soil in 8-inch pots in the greenhouse during the spring and summer. A total of 75 plants were divided equally for the following treatments:

1. Control; plants flowering and fruiting normally.
2. As group 1, but in addition 0.5 per cent indole butyric acid in lanolin was applied to the fruit as soon as the stigma and style dried up.
3. Indole butyric acid, 0.5 per cent in lanolin, was applied to the emasculated flower, and parthenocarpic fruits produced.

Table II gives the average number of fruits produced per plant and the total fresh weights in grams of the fruit and vegetative parts.[2]

Here, as is also noted in groups 1, 2, and 3 of the cucumber experiment, the greatest yield of fruit was obtained from plants producing

TABLE II—RESULTS WITH PEPPERS

Group and Treatment	Number Fruits	Weight Fruit (Grams)	Weight Tops (Grams)	Total Weight (Grams)
1. Control	10.85	325	131.5	456.5
2. Control +.5 per cent β indole butyric acid	9.65	271	130.5	401.5
3. Parthenocarpic fruit	14.20	268	146.5	414.5

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[2] It is customary to express the yields of fruit in fresh weight. Dry weights exhibited the same differences.

normal seeded fruits. From the standpoint of available food, one would expect to obtain greater yields from plants producing seedless fruits, because seeds are very rich in organic reserves and no food would thus be dissipated in the seed. However, quite contrary results were obtained; yields instead of being higher, are significantly lower. Obviously, seedless fruits must lack something found in those containing seeds. Can the affects of gametic union, and the subsequent presence of developing embryos account for these differences in yield?

If the inhibiting effects of the fruit on vegetative growth are considered, it can be observed that the retardation in the case of seedless fruits is decidedly less than that due to normal seeded fruits. In other words, the vegetative growth is much greater where plants produce seedless fruit. This can probably be explained by the fact that on plants producing parthenocarpic fruits the yield was less and no nutrients were required for seed production. It is also possible that the developing embryos, in addition to an initial stimulus, may in later stages, produce an inhibitor, which slows up or prevents further vegetative extension.

Experiments with Cherries

To determine if the effect of gametic union could be observed in fruit trees, the following experimental treatment was performed with twigs on 10-year-old Montmorency cherry trees:

1. Control; normal fruiting.
2. Twigs disbudded just prior to anthesis.
3. Twigs defruited, about 10 days after full bloom.

Only such twigs were selected for these tests which had made a uniform growth in length of about 15 centimeters the previous season. All vegetative buds were removed except one terminal. Since vegetative and flower buds are separate and easily distinguishable, no difficulty in this respect was encountered. A total of about 100 twigs was used in this experiment. For determining the effect of gametic union and the presence of fruit on the current vegetative growth, the amount of new growth for the season was taken as an index.

Table III gives the amount, in grams, of dry matter produced, and the average length in centimeters of new growth for each treatment.

TABLE III—Results with Cherries

Group and Treatment	Leaves (Grams)	Stems (Grams)	Fruit or Flowers (Grams)	Total (Grams)	Lengths (Cm)
1. Control..................	56.6	10.9	38.1	105.6	12.2
2. Deflorated...............	61.0	11.9	12.2	85.1	13.1
3. Defruited........	63.0	13.5	17.8	94.3	14.1

The results show that twigs on a tree behave largely as separate individuals. The effect of the presence of fertilized embryos is apparent. In spite of the fact that more food was no doubt utilized by the young fruits than by the flowers, the vegetative growth was greater in the defruited group, being 76.5 grams as compared with 72.9 grams in the deflorated group. The greatest amount of dry matter, however, was produced on twigs with developing fruit. This was perhaps due to the embryos being permitted to exert their influence over a longer period, and probably drawing reserves from other parts of the tree.

CONCLUSION

The data herein presented indicates that as a result of sexual reproduction, the vegetative parts of a plant are vitally influenced. Due to fertilization of flowers, the growth of not only the fruit but also the vegetative portions of the plant are stimulated. It seems reasonable to conclude that some catalyst or substance of hormone-like nature must be produced at the time the male and female gametes unite, resulting in increased vegetative development. Triple union, or endosperm formation, may also be effective in the production of a stimulatory substance. Investigations are underway to extract and isolate such a substance or substances.

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Climate in Relation to Deciduous Fruit Production in California II. Effect of the Warm Winter of 1940–41 on Apricot, Plum, and Prune Varieties in Northern California

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A SEVERE, abnormal dropping of flower buds in northern California orchards during January, 1941, on peach, nectarine, apricot, plum, and prune varieties led to a survey of the trees in the varietal collections of the University of California at Davis. Since the results of the peach and nectarine observations were published in 1941 (1), the present paper will discuss the effect of climate on the fruit production of 119 apricot, 53 plum and prune, and two plumcot varieties after relatively high winter temperatures. As already shown (1), the winter of 1940–41 was the mildest of the 12 winters in which the hours at or below 45 degrees F were used as a basis of study.

The conditions and ages of trees noted in the previous report (1) are true for the varieties now under consideration. Trees were observed three different times — at the swelling of the flower buds, at full bloom, and at the time the young fruit was present. Consistent results were observed for each of the three surveys. Only one-eighth of the plum and prune varieties in the University varietal collections was checked, since only the important California commercial varieties, together with a few of interest to the plant breeder, were considered.

Varieties were again placed in one of four groups, depending upon the amount of bud drop: No bud drop, Class I; slight bud drop, Class II; moderate bud drop, Class III; and heavy bud drop, Class IV. Complete descriptions of these classes have previously been given (1). The results are shown in Tables I and II, with the varieties arranged alphabetically in their respective classes.

APRICOTS

As will be noticed, more than half of the apricot varieties suffered a severe bud drop in 1941 and hence produced no fruit crop. No varieties were observed to have their full complement of buds (85 to 100 per cent). Royal (including Blenheim) and Tilton, the important commercial apricot varieties in California, produced in 1941 about one-half a normal average crop of fruit. The tonnage was higher in 1941 than in 1940 when the smallest crop (102,000 tons, when acreage is considered) on record (2) was produced. Although there were fewer cold hours (677) at Davis, California, during the 1940–41 season than during 1939–40 with 961 hours, the trees would have had an excellent chance to recover and to produce a full crop after the light 1940 yield if it apparently had not been for the abnormally mild winter of 1940–41.

PLUMS AND PRUNES

French, the important prune in California, which was observed to

TABLE I—APRICOT VARIETIES RANKED ACCORDING TO AMOUNT OF BUD DROP (DAVIS, CALIFORNIA, 1941)

Class I (No Bud Drop)

No varieties observed to fall in this Class

Class II (Slight Bud Drop)

Barry
Bizant Royal
Black
Blenheim†
Cluster
Early Cluster
Hybrid No. 2
Janet†
King City Blenheim†
Losse Blenheim†
McKinley
Miner
Nellie†
Newcastle
Newcastle Early
P. I. 34265
Riland
Routiers Peach†
Royal
Santa Fe
Sardinian
Sophie
Stephens
Superb
Wolfskill Royal†

Class III (Moderate Bud Drop)

Bongoumet†
Boulbon†
Burtons Royal Seedling
B. W. Marshall
Colorado
Cream†
Derby Royal
Early May
Grace
Great Plains
Griffin Choice
Harris
Hemskirke
Hersey Moorpark†
Kaleden
Large Early Montgamet
Lewis
Luizet
Maxson
Meyer Giant†
Mognaga
Montgamet
New Large Early
Oullins Early
Peach
Pringle Late
Sharpe
Thissel No.2
Thissel Seedling†
Tilton
Wenatchee
Wenatchee Moorpark†

Class IV (Heavy Bud Drop)

Acme
Alameda Hemskirke
Alexander
Alexis
Bairam-Ali
Beauge
Blackman
Blush
Bolton
Brady
Breda
Casaba
Catherine
Chinese
Chrisomelo (P. I. 34269)
Cutler
Derby
Double Flowering
Early Golden
Early Rivers
Florizan
Garlach
Giallo di Fortons
Gibb
Gilbert
Grosse Peche
Hersey Moorpark
Jap
Japanese (P. I. 45523)
J. L. Budd
Jones
Lampasas
Lowe
Mammoth White
Moorpark
Murgab (P. I. 32834)
Nicholas
Noble
P. I. 20072
P. I. 28960
P. I. 38281
P. I. 38282
Pringle
Red River
Rivers
Rualt
Sloan
Smyrna
Snowball
Sparks Mammoth
St. Ambroise
Stella
Stewart
Sugar
Tentazione
Thompsons Early
Toyahvale
Trevatt (P. I. 68355)
Upham No. 1
Upham No. 2
Wiggin
Wilson

†This variety is borderline between this class and the one with the greater bud drop.

have droppd its buds only slightly, produced a good crop in 1941. Most of the important plum varieties—for example, Imperial, Kelsey, Pond, Santa Rosa, Wickson, Formosa, Gaviota, Giant, Grand Duke, President, Satsuma, Sugar, and Tragedy — were curtailed in production because of either a moderate or a heavy dropping of the flower buds during the spring of 1941.

Considerable variation exists among varieties of the several *Prunus* species considered. Varieties of both *P. domestica* and *P. salicina* (including Japanese hybrids) are found in each of the four classes. Furthermore, Damson (*P. insititia*) was observed to fall in Class II (slight bud drop). Class IV (heavy bud drop) contains Pissardi (*P. cerasifera*), El Dorado (*P. salicina* x *P. simonii*), Flickinger (*P. salicina* x *P. americana*), Inca (*P. salicina* x *P. simonii*), and Miracle (*P. domestica* x *P. insititia*).

TABLE II—PLUM AND PRUNE VARIETIES RANKED ACCORDING TO THE AMOUNT OF BUD DROP (DAVIS, CALIFORNIA, 1941)

Class I (No Bud Drop)

Duarte
French 1414
Sergeant

Class II (Slight Bud Drop)

Beauty
Becky Smith
Burbank†
Burton Date Prune†
Climax†
Coates 1403
Damson
French
Golden Drop
Green Gage
Sharkey

Class III (Moderate Bud Drop)

Abundance
Apex
California Blue
Coates 1418
Hungarian
Imperial
Kelsey†
Late Tragedy
Pond
Santa Rosa
Standard
Washington
Wickson
Yellow Egg

Class IV (Heavy Bud Drop)

Champion
Clyman
Diamond
El Dorado
Emilie
Flickenger
Formosa
Gaviota
German
Giant
Grank Duke
Imperial Gage
Inca
Italian
Late Satsuma
Lombard
Miracle
Pissardi
President
Quackenboss
Rutland Plumcot
Satsuma
Sharp
Sharpe Plumcot
Sugar
Tragedy
Yellow Gage

†This variety is borderline between this class and the one with the greater bud drop.

PLUMCOTS

The plumcots considered here (Rutland and Sharpe) are classified with the plum and prune varieties. These hybrids showed a heavy bud drop, with a correspondingly poor fruit crop.

CONCLUSION AND SUMMARY

One hundred and nineteen apricot, fifty-three plum and prune, and two plumcot varieties were observed in the spring of 1941 for their susceptibility to dropping their flower buds after the warm winter of 1940–41. These varieties were placed in four classes depending upon the amount of flower-bud drop observed.

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Apple Varieties: Behavior of Two Hundred Varieties Following the Freeze of November, 1940[1]

By B. S. PICKETT and H. L. LANTZ, *Iowa Agricultural Experiment Station, Ames, Iowa*

THERE are numerous descriptions of injury to apple trees caused by a blizzard which swept from northwest to southeast over a vast region which roughly followed the Missouri River from South Dakota to Missouri, November 11 to 15, 1940. Injury assumed all the forms common to low-temperature midwinter damage except root killing. Crown, trunk and crotch injury, patch killing on branches, die-back from tips, outright killing of entire tree tops, killing of fruit buds and spurs, and even killing of leaf buds and small areas of bark and wood at the base of leaf buds occurred on a widespread and extensive scale. Varietal response of apples to the freeze departed in interesting ways from accepted behavior, and a record is presented herewith of the recovery or injury of about 200 named varieties and selected seedlings growing in an experimental planting at the Iowa Agricultural Experiment Station at the time of the disaster.

The varieties in this orchard were top-grafted by the budding process in the branches of 2-year-old Virginia Crab apple trees. The stock trees were planted in April 1925. Budding of most varieties was completed in 1926, but a limited number of stock trees were preserved for additions of promising new varieties as they might be introduced. The heads of the trees on which observations were made were 14 years old when the freeze occurred. The trees were large for their ages, except in a few cases where stock and scion were incompatible (1), and bore crops up to 20 bushels per tree in 1940. In commercial orchards they would be regarded as approaching full bearing.

The most significant study of the injury combined ratings of trunk, branch, crotch and bud injury, with an additional rating of the growth made by the trees during the season of 1941. It is reported as recovery value.

Only six named varieties, Anoka, English Russet, Malinda, Peter, Repka Malenka and Hibernal, and 13 seedlings from various sources which were undergoing second and third tests, were entirely uninjured. Thirteen named varieties, including Early Red Bird, Edgewood, Folwell, Hawkeye, Haralson, Greendale, Kendall, Lansingburg, Milton, Secor, Virginia Crab, Wealthy and Yellow Transparent, and 11 seedlings which were undergoing second and third tests, showed upwards of 90 per cent recovery value. Twenty-three named varieties, including Ashton, Baldwin, Brilliant, Charlamoff, Close, Cortland, Duchess, Erickson, King David, Lawfam, Lobo, McIntosh, Melba, Northwestern Greening, Paragon, Red Duchess, Red Gravenstein (N. Y. strain), Ribston, Sharon, Sheriff, Turley, Wedge and Wolf River, and 25 seedlings, were classed as having recovery values of 70 to 90 per cent.

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[1] Journal Paper No. J-978 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 288.

All of the varieties mentioned above will make profitable recoveries so far as injury from the freeze is concerned.

The next classification, however, includes a group of varieties and seedlings whose profitable recovery is in question. They are rated as having recovery values ranging from 75 to 50 per cent. Some might bear several fair crops and die after a few years; others might live quite a long time, bearing crops on half or two-thirds of a normal top. A commercial orchardist would be in doubt about retaining them but would probably do so while waiting for new plantings to come into bearing. They would be retained in home orchards without question. Under all conditions they would need pruning to remove dead branches, fertilizing to stimulate recovery growth, and be better for some simple forms of tree surgery. There were 20 varieties, including Ben Davis, Black Jon, Colorado Orange, Early McIntosh, Fameuse, Jonathan, Langford Beauty, Longfield, Mammoth Black Twig, Minkler, Paradise Winter Sweet, Pennock, Perry Russet, Pound Sweet, Red June, Salome, Williams, Willow Twig, Windsor and Winter Banana, and 13 seedlings under second or third tests, in this classification.

Forty-five named varieties and four seedlings were rated not worth saving. They are, however, divided into two classes, one rated as having 25 to 50 per cent recovery value and the other little or none. Included in the group which has 25 to 50 per cent recovery value are Anisim, Chenango, Canada Baldwin, Delicious, Gilliflower, Golden Delicious, Grimes, Hume, Jefferis, Joan, Macoun, Northern Spy, Red Fameuse, Richared, Starking, Wagener, Westfield, Winesap and two seedlings. Completely crippled, mostly killed outright, were 27 named varieties, including Allen Choice, Baltimore, Benoni, Bramley (seedling), Dyer, Greenville, Huntsman, Hubbardston, Lady, Maiden Blush, Medina, Newfane, Opalescent, Orleans, Red Gravenstein (Washington), Red Spy (New York), Rhode Island Greening, Rome, Roxbury, Stayman, Summer Queen, Sweet Delicious, Tolman, White Pippin, Yellow Bellflower and York, and two seedlings.

The authors recognize the difficulty of making generalizations from data of the kind presented herewith, but believe the record itself is too valuable to be omitted from the general accumulation of information bearing on low temperature injury.

Attention is invited to a few interesting departures from responses of certain well known varieties to ordinary midwinter low-temperature injury. Three trees of Baldwin and a Ribston promise a very satisfactory recovery, and two members of the Winesap group, Paragon and Turley, came through quite well. A red Gravenstein sport from New York State shows a good recovery, while another from Washington was killed. Northern Spy, White Pippin and Tolman, known to be resistant to low temperatures in midwinter, were injured beyond profitable recovery. These observations support the theory that the injury occurred because the injured tissues were not mature enough to resist the not very low temperature (—2 degrees F at Ames) which accompanied the freeze.

It was disappointing that none of the great market varieties were found in the first three classifications, with the exception of McIntosh, a variety which is not profitable in Iowa. Jonathan was severely crippled, and Grimes, Golden Delicious and the red Delicious group had all to be classed as not profitably recoverable. These facts, of course, emphasize the need for varieties of good quality which are more resistant to the idiocyncracies of climatic conditions in the Upper Mississippi and parts of the Missouri Valleys than the standard varieties. The record furnishes substantial data justifying plant breeding programs and encouraging further breeding efforts. Haralson, a product of breeding in Minnesota; Secor, Edgewood, Hawkeye and Sharon, Iowa seedlings; and Cortland, Kendall, Milton, Lobo, Melba, Turley and Lawfam, definite products of other breeding programs, comprise 75 per cent of the worth while varieties which promise a high recovery value.

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Fruit Tree Injury Resulting From the Midwest Blizzard of November 1940[1]

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THE blizzard of the week of November 11 to 16, 1940 was a major disaster to the horticultural industry in the states of Iowa, Missouri, Nebraska and Kansas. To appreciate the full effect of the storm on horticultural plants one must consider the conditions which preceded the freeze. The fall had been unusually warm and sufficient moisture was present in the soil to keep plants and trees in an active growing condition up to the time of the first killing frost which occurred on November 7 when the temperature dropped to only 24 degrees F. It was after a season of very heavy production and when apple trees were still in full leaf that the storm struck the middlewest. On November 8, 9 and 10 warm weather prevailed and during that period nearly 2 inches of rain fell in central Iowa. On November 11, the storm moved in and continued until the 15th. The temperature at Ames, Iowa on the morning of November 11 was 51 degrees F; by noon a 50-mile gale had developed and by night 9 degrees F was recorded. Minimum temperatures on the four succeeding dates were 4 degrees F; —2 degrees F; 2 degrees F and —2 degrees F. In the southwest quarter of the state conditions were even more severe and temperatures as low as —9 degrees F to —15 degrees F were reported. In southeastern Iowa, east of Marshalltown and south of Cedar Rapids temperatures were slightly higher than those at Ames; in general, 0 degree F being the minimum.

Comparable storm conditions also prevailed in that section of Missouri lying west of a line drawn from Hannibal through Columbia and Springfield. Eastern Nebraska, which included the principal orchard sections, experienced temperatures like those of Iowa. In Kansas the eastern half of the state, from the Nebraska to the Oklahoma line, reported temperatures from —4 degrees F in the north to 4 degrees F on the southern boundary. Temperatures in sections of western Illinois approximated those of adjacent sections in Iowa and Missouri but the cold evidently caused less damage to fruit there than it did in Iowa and Missouri.

Unseasonal freezes of the November 11 type are not common in Iowa, but nevertheless they have occurred. In the first annual report of the Iowa State Horticultural Society, published in 1868, a cold spell was reported as happening late in October. In this case there was no frost until October 26; then there was rain attended by snow and a hard freeze, which was reported to have killed three-fourths of all apple trees in southwestern Iowa.

Again on October 28, 1925, a cold spell developed with temperatures dropping to 5 degrees below zero. This freeze caused heavy damage to young trees in the nurseries, but orchard trees, although they showed evidences of bark and wood injury, came through with little permanent damage.

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[1] Journal Paper No. J963 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project 466.

Within a few days after the November 1940 storm subsided it was discovered that plants had been injured. The first examination showed that leaf buds, fruit buds, fruit spurs and terminal growth were badly damaged, as indicated by a discoloration of the critical tissues of bark and wood. On many varieties, wood over 2 or 3 years old showed injury back to the main limbs which, in many instances, were apparently uninjured. The injury began again below the main crotch and extended into the trunk down to the ground line.

Shortly after the freeze, a comprehensive state-wide orchard survey was made by members of the horticultural staff of Iowa State College, and evidences of extensive damage to orchard trees were found in all parts of the state. Southwestern Iowa, in which are located the most extensive orchard plantings, had heavier injury than did the eastern or southeastern sections. In adjoining states it was discovered that orchards in southeastern Nebraska, northwestern Missouri and northeastern Kansas had also suffered severe injury. Nurseries in all these sections sustained heavy losses to young trees which were undug at the time of the freeze.

Fruiting plants which were damaged included the apple, peach, pear, sour and sweet cherries, apricots, blackberries and red and black raspberries. Currants and gooseberries were only slightly injured. Native plums were uninjured but Japanese and sand cherry hybrids and European varieties were definitely hurt. Grapes apparently were uninjured but later showed considerable bud and cane killing. Strawberry plants which were unmulched at the time of the cold snap, where not entirely killed, were injured in the roots and dormant fruit buds. This injury was evidenced at picking time by low yields of small, knotty berries.

Injury to ornamental plants was most noticeable in the evergreen group. In all parts of the state Junipers, including Pfitzer, Irish, Swedish, Greek, Chinese and other selected types fared badly. Douglas-fir, Yellow Pine, Arborvitae and Yew were also damaged. Roses in the hybrid tea and hybrid perpetual group were killed or badly injured. Even hardy roses, like the *Rosa rugosa*, were killed to the ground line. In the main, the commonly planted hardy ornamental shrubs escaped serious injury. The same holds true for deciduous trees; the exception being ornamental crabapples, some varieties of which were killed or badly hurt. Of all ornamental trees the Chinese Elm suffered most. Throughout the midwest states fully 95 per cent of the trees of this species in all ages were killed outright. If this species is to be replanted it should be done with trees asexually propagated from the best types which withstood the cold. It was interesting to note that practically none of the plant material native to the midwest region was severely injured.

Until well into the 1941 season it was impossible to determine the nature and extent of the injury caused by the November storm. As the season advanced it became evident that in all fruit varieties there were trees that had been killed outright even to the extent that sprouts did not start from the apparently uninjured root parts. This suggests that practically no manufactured food had migrated back to the roots up to the time of the freeze. To account for this we have the active growing condition of the trees and the depletion of food reserves through the production of a heavy crop preceding the storm.

A microscopic examination of injured tissue in various parts of the tree showed a dark browning of the outer bark. That the cellular structure was disrupted was evidenced by exudation of sap which gave the outer bark a water soaked appearance. Such bark adhered firmly to the underlying sap-wood which was also severely injured, as denoted by a coloration of a deeper shade than that of the bark. A microscopic examination of the injured tissues revealed a general disruption of the cells of the cambial region as indicated in Fig. 1.

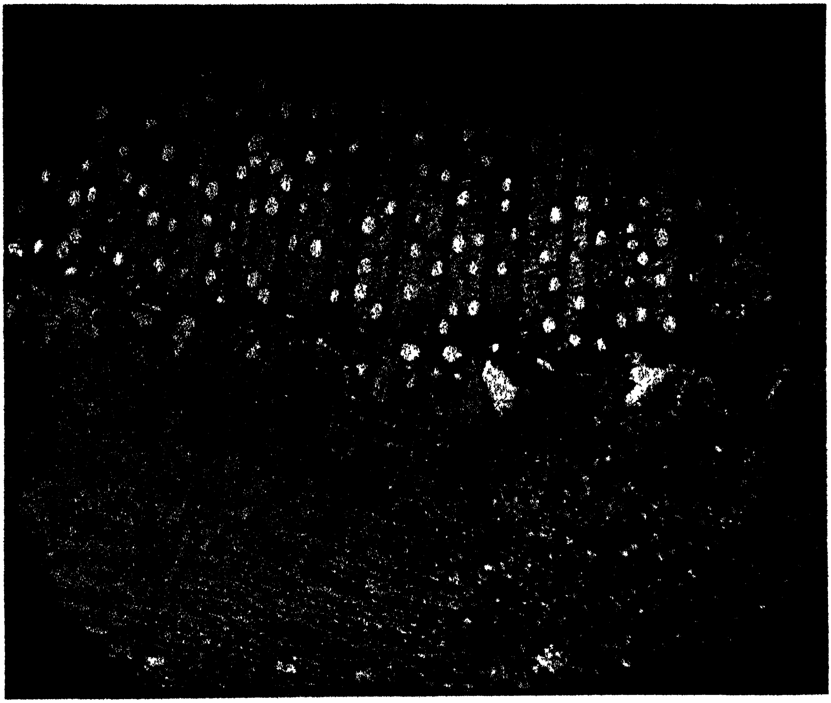

FIG. 1. In severely injured portions there was a general breakdown of the tissues in the cambial region between the bark and sap-wood.

In some cases where injury seemed severe as indicated by browning of the inner bark and sap-wood tissues, regeneration was eventually accomplished. This happened most frequently with hardy varieties like Virginia Crab. How this regeneration was affected is explained in Fig. 2. This microscopic section shows that there was a thin line of cells in the phloem region between the inner bark and the outer sap-wood which was uninjured and capable of regenerating new tissue.

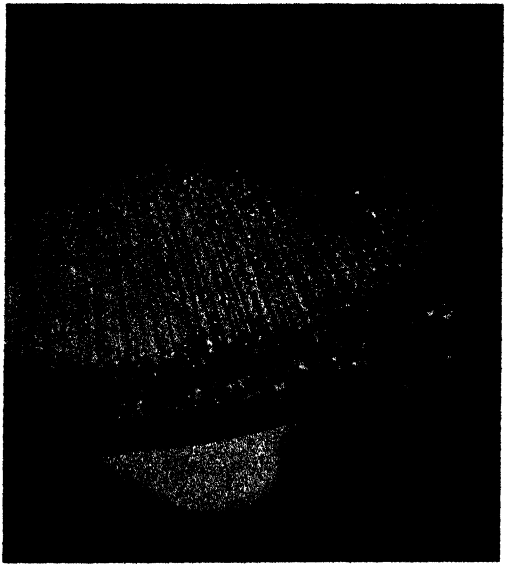

FIG. 2. The distinct dark line (indicated by arrow) consists of injured cells in the outer sap-wood. Above the dark line is a row of live cells which are a part of the inner bark in the phloem region.

As a result of the storm many types of injury were outlined as indicated by the regeneration of bark tissue or lack of the same. In the apple which is the main commercial fruit of the region certain varieties like Duchess, Yellow Transparent, Wealthy, Haralson, Hawkeye Greening and others were uninjured; Maiden Blush, Chenango, Stayman, Delicious, Grimes, Golden Delicious, York, Rome, Missouri Pippin and Virginia Beauty were killed outright or severely injured in all parts of the tree.

The other forms of injury which developed were the killing of terminal growths of 1, 2, and 3 years of age; killing outright or severe patch injury to lateral and main limbs; crotch injury and trunk injury in various degrees of severity. Occasionally in certain varieties like Jonathan the entire crotch and limb structure was uninjured but the trunk was girdled by bark injury to the extent of 25 to 100 per cent of its circumference. Such instances serve to demonstrate the value of the use of a hardy intermediate stock as the trunk stem-piece.

On practically all varieties which survived in whole or part there was severe damage to fruit spurs and to lateral fruit and vegetative buds. In most cases on surviving varieties there must be a complete replacement of the fruit bud and spur organization and this will be largely from latent or dormant buds scattered over the entire tree.

The force of the storm which was of blizzard proportions was from the west and southwest. As a result, the heaviest injury on surviving trees is on the west and southwest sides with only a few limbs on the northeast uninjured.

It is rather difficult to draw any conclusions as to the actual hardiness of varieties as judged from the injury resulting from the November storm. The known cold resistance of varieties was not a complete index as to their hardiness under the conditions imposed by the freeze. Some of the recognized hardy varieties were badly injured while some of the tender sorts escaped damage.

Apple varieties like Duchess, Wealthy, Yellow Transparent, Haralson, Hawkeye Greening and Willow Twig were uninjured in Iowa nurseries and orchards. The new varieties, Edgewood, Secor and Sharon, recently introduced by the Iowa Agricultural Experiment Station, fared better than the standard sorts such as Grimes, Delicious, Golden Delicious and members of the Winesap group. In general, new varieties developed in Iowa, Minnesota and Canada were superior in cold resistance to the varieties developed in eastern states. The McIntosh crossbred types were the least injured of the New York varieties while Orleans, Kendall, Newfane and Sweet Delicious were badly injured or killed outright.

In the states of Iowa, Missouri, Nebraska and Kansas the full extent of damage from the November 1940 storm to fruit trees may not be known for 2 or 3 years but enough is now known to make a fairly reliable estimate. In Iowa where the apple is the principal fruit crop, commercial varieties like Jonathan, Red and Golden Delicious, Grimes, Stayman and Winesap have suffered a loss in trees about as follows: southwest Iowa, 90 per cent; southeast Iowa, 70 per cent, except in a line of counties along the Mississippi from Scott on the north to Lee on the south which shows a loss of only 35 per cent. With other fruits, pears were apparently badly injured but show at the end of the 1941 season a good recovery in the hardier sorts. Peaches and sour cherries are almost a total loss in all sections.

In Missouri the heaviest losses are in the northwest corner where it is estimated that there is a loss of nearly 100 per cent in the stone fruits, and 75 per cent in apples and pears. In the west-central district the loss in apples may be 25 to 40 per cent, while the stone fruits will average 75 per cent. East of this western district the injury to apples may average 15 to 25 per cent while stone fruits show a loss of 60 to 70 per cent.

In Nebraska the loss to winter apples from the freeze is about 80 per cent, the main survival being in Jonathan which shows in the survivors severe injury on the southwest side. Sour cherries which are grown in the Nebraska City district were killed to the extent of 95 per cent in Montmorency and English Morello while Early Richmond took a loss of 50 per cent. European and Japanese plums and peaches are almost a complete loss. Pears were badly injured but have made considerable recovery.

In Kansas, as based on a survey of 20 counties situated in the eastern half of the state, the loss in trees has been estimated at 50 per cent, with certain counties reporting 90 to 100 per cent losses.

November, 1940, Cold Damage to Fruit Plants in Illinois

By V. W. Kelley and R. L. McMunn, *University of Illinois, Urbana, Ill.*

DURING the period November 11 to 15, 1940, a severe cold wave crossed the Northern Great Plain States, Iowa, northern Missouri, and into western Illinois. Temperatures were low enough in states to the west of Illinois to cause widespread killing and injury to fruit plants. By the time the cold air mass had reached Illinois temperatures had moderated to such a degree that far less damage was done than in states to the west. Although the damage was less in Illinois and relatively few trees were killed outright, it seems advisable to place on record the extent of the damage and observations that have been made, because in Illinois we possibly had an opportunity to make certain observations that probably could not be made in the area where the trees were killed outright.

In Illinois, killing and injury was confined almost entirely west of a line drawn north and south from the eastern boundaries of Mercer and Warren Counties. The most serious damage in this area seems to be centered in the northern half of Adams County and the southern half of Hancock County. An extension of this area extended in a south-southeast direction across Pike County and into Calhoun County. Within the damage area is located the principal apple-producing section of the state, centering in Calhoun and Pike Counties, the western part of Greene and Jersey Counties, and also into Adams County. Commercial apple orchards are to be found in the other counties but not in large numbers. Within this area is also located the only large commercial grape region of the state (around Nauvoo, Hancock County). Around Quincy (Adams County) are commercial plantings of small fruits. Other tree fruits are planted sparingly in the damage area; however, there are a few peach orchards of 5 to 20 acres in area.

Temperatures and Precipitation

Previous to the cold of November 11, the temperature had been relatively high. No frost or freezes had occurred up to that time in the area where damage occurred. On the morning of the 11th, temperatures in the damage area were as follows: Moline (Rock Island County), 58 degrees F; La Harpe (Hancock County), 56 degrees F; Quincy (Adams County), 56 degrees F; and White Hall (Greene County), 58 degrees F. In the late morning a very high wind, reaching 46 miles per hour at Springfield, 29 miles per hour at Peoria (nearest wind reporting station in Illinois), and 41 miles per hour at Keokuk, Iowa (across the Mississippi River from Hancock County), swept in from the northwest. Temperatures dropped very rapidly and within a few hours readings close to or below freezing prevailed throughout the damage area. Minima on the night of the 11th were: Moline, 15 degrees F; La Harpe, 22 degrees F; Quincy, 24 degrees F; and White Hall, 27 degrees F. Minima on the 12th were 10 to 12 degrees F throughout the area. The lowest temperature during the period of the cold occurred on the night of the 13th, when temperatures were recorded as follows: Moline, 6 degrees F; La Harpe, 3 degrees F; Quincy, 7 degrees F; and White Hall, 10 degrees F. Unofficial readings in the open country in northern Adams County and southern Hancock County were reported as low as —4 degrees F, with several readings of zero reported. Following the cold of the 13th, temperatures rose rather rapidly and were generally above freezing until November 28, at which time a second cold wave, extending until December 3, prevailed. During this period readings were, in general, near zero, with an official reading at La Harpe of —4 degrees F. The remainder of December was mild; the monthly normal was the highest in 10 years. It is felt that all the damage in Illinois occurred during the cold of early November, and that of November 28 to December 3 caused little or no damage.

Precipitation during the summer and early fall had been considerably below normal, but not so much as to cause deep-rooted plants to suffer. Above normal rainfall during October, followed by light rains during the first five days of November, was sufficient so that with the relatively high temperature trees that retained their leaves apparently remained in a growing condition.

At the time of the cold the leaves on apple trees that had been sprayed during the summer were still on, were dark green, and were apparently functioning. Apple trees under 5 or 6 years of age generally were not given a complete spray schedule, thus scab and insects caused defoliation before the cold wave. Grapevines had dropped all their leaves, while those of peach trees were mostly off. Pears, cherries and plums had dropped a part of their foliage. The presence or absence of foliage on the trees seemed to have had a direct bearing on the severity of damage, as will be mentioned in a later paragraph.

Damage to Fruit Plants

Fruit Buds:—Although the fruit buds of tree fruits are generally the most tender parts to winter cold, they were, in general, the most hardy to the 1940 early winter cold. Apples came through with almost a 100 per cent survival. Peach fruit buds showed from about 75 to 100 per cent survival, depending upon variety and exposure of the plantings. In one small planting in southern Hancock County, there was a 100 per cent bud survival, even though the trees died from the effect of the cold (trunks and larger scaffolds killed). Plums survived almost 100 per cent (mostly varieties of American species and hybrids, few European and Damson, no Japanese). Sour cherry fruit buds generally were not killed, even though the spurs and current season shoots were severely injured and even killed. (In Hancock County, cherries bloomed but set a light crop, due to the death of most of the spurs.) On the one sweet cherry tree found in the damage area, the fruit buds on the spurs, along with the spurs, were killed, yet those on the shoots survived 100 per cent. Pear flower buds showed almost a 100 per cent survival. In Hancock County, the bark and wood of the spurs and inner bud scales was killed, and up until shortly before bloom it was thought that the cambium was dead in the spurs. Such was not the case, however. The cambium was alive and from it new wood and bark was formed, and by the fall of 1941 much of the old killed bark on the spurs was being "sluffed-off". These trees bore good crops.

Raspberries in the Quincy region suffered almost a 100 per cent loss of buds. Killing extended but an eighth to a fourth of an inch above and below the bud, with no killing of the cane in the internodal sections. In the Quincy area, strawberries suffered severely, with some plantings being entirely killed. (No patches were mulched at the time of the cold). Grape buds came through with almost a 100 per cent survival. Very light killing back of some terminals was reported in a few vineyards, but it was in general not as severe as during most seasons.

Roots:—The roots of plants were not injured. This is not surprising, when it is recalled that the temperature had been relatively high before the cold wave, and the cold was of so short a duration that the soil did not freeze to any depth.

Smaller Branches and Limbs:—With the exception of the peach and sour cherry, very little or no injury was found on the smaller branches and limbs. With these fruits, light to severe browning of the bark on shoots and smaller branches was found on most trees. This injury did not seem to be serious, because trees so injured produced good crops, unless the cambium was killed on the trunk or scaffolds.

Trunk, Scaffold and Larger Limbs:—By far the most serious damage was done to the trunks of trees, far lesser damage to the scaffolds, and usually none to light injury to the larger limbs originating from the scaffolds. Almost invariably there was a distinct line of demarcation between injured and non-injured tissue from 1 to 2 inches above the ground line. For the most part, injury was confined to the bark, this tissue in the most seriously damaged trees being killed, while in less severely injured trees there was some browning but not apparent killing of the entire tissue. On severely injured trees cambium was frequently killed, along with the youngest sapwood. However, many trees that were severely injured had islands of live cambium scattered over the trunk. From these islands of cambium new bark and sapwood originated in 1941 and have bridged over the injured areas. Injury in general was more serious on the lower part of the trunks, then decreased in severity toward the head of the tree. Frequently no evidence of injury was found higher than the lower scaffolds, even though severe trunk injury was evident. On the trunks and also scaffolds, the most serious damage was invariably found on the side towards the prevailing wind. With apples, on many trunks the bark and cambium was killed on the windward side of the trunk, while no injury whatever could be found on the leeward side. With bearing peaches throughout the damage area, the trunk bark was generally severely injured (occasionally killed) entirely around the trunk and on the scaffolds. Except in Hancock County practically all such injured trees recovered in 1941 and produced good crops. As mentioned in a preceding paragraph, the few peach trees in Hancock County were mostly killed. Pear trees in the Hancock County area had the bark killed, along with the younger sapwood. Up until growth started in the spring of 1941, it was thought that the cambium on such trees was killed. This did not prove to be the case; such trees developed new wood and bark from the cambium and by the fall of 1941 much of the old dead bark had dropped off, leaving large areas on the trunk as smooth as that on young trees. In other areas injury to pears was not so severe. With apples, crotch injury was not generally found, except on the more susceptible varieties. Injury to scaffolds and larger limbs was rarely found, except with the most susceptible varieties. Maiden Blush and Winter Banana appear to have suffered the greatest damage to the larger limbs. In two orchards, the small blocks of Maiden Blush died after ripening the 1941 crop. The growers reported that such fruits were not up to quality and seemed to be heavier than normal.

Cherries, in general, were severely injured on the trunks and at the crotches. Plums exhibited little or no injury. Apples under 5 or 6 years of age and other fruits not of bearing age suffered no injury. Apples over about 20 years of age were, in general, not injured.

From observations made during the winter and summer the following apple varieties suffered the greatest injury: Winter Banana and Maiden Blush, wherever found, were killed; York, Rome, Delicious (and sports) and Golden Delicious were generally injured and occasionally seriously injured; Ben Davis, Gano, Willow, (McIntosh, Fameuse, Cortland, Northwestern, only a few trees found), Transparent, Minkler, Grimes, and Senator escaped without injury; Stayman, Winesap and Jonathan in some instances showed rather severe injury but, in general, escaped with little or no injury.

CULTURAL PRACTICES AND EXPOSURE IN RELATION TO DAMAGE

The soil cultural treatment given the orchards during the summer and fall had a direct bearing on the severity of damage. Invariably, where orchards were cultivated late or a summer cover crop was disced down in preparation for a winter cover, such orchards suffered the greatest damage. This was evident throughout the damage area. The degree of exposure of the trees to the full force of the wind also was a factor in the severity of damage. Orchards on higher ground or exposed to the full blast of the wind invariably were damaged more than orchards on lower ground or those not exposed. Almost invariably, with orchards containing susceptible varieties and exposed to the full force of the wind, damage was found on the outside rows on the windward side of the orchard, with decreasing injury on successive rows away from the outside rows.

In no case could the amount of crop be associated with the severity of injury. In the Quincy area, killing of the bark and cambium above ring girdled areas (made in the spring of 1940) occurred on Delicious and Winesap, even though good healing-over had taken place. No such injury was apparent on Jonathan. In Calhoun County, 30-year-old Transparent and Chenango trees that had a part of the limbs ringed and scored were killed above the treated areas. Some injury above scored areas was also found.

DISCUSSION

From the observations made, it appears that lack of hardening-off of the plant tissue was greatly responsible for the severity of injury. Thus, with plants that had dropped the foliage and thus were hardened-off, little or no injury was found. Also, the fact that the trunk tissue hardens-off later than that of the smaller branches and limbs supports this conclusion, because the trunks suffered far more injury than the limbs and buds. That the wind also had a direct effect on the severity of injury cannot be discounted. The effect of the wind on the plant tissue cannot be stated at this date. There is a possibility that the high wind may have caused a very rapid water loss on the windward side of the trunks, which may have been great enough to result in the death of cells. In preliminary tests in a cold storage, it was found that branches on which a blast of air was directed cooled much more rapidly than limbs on which no air was directed. Thus, the rate of cooling may have had an indirect part in the injury.

Injury to Tung Trees by Low Temperatures Occurring in November, 1940

By DONALD L. FERNHOLZ and GEORGE F. POTTER, *U. S. Department of Agriculture, Bogalusa, La.*

THE cold wave of mid-November 1940, which caused severe damage to many orchards in the middle western United States, swept down and across the deep South, exacting a toll from tung orchards from Texas to Florida. Weather conditions prior to the date of the freeze were such as to render the trees extremely susceptible to injury from low temperature. Rains occurred in some parts of the tung belt during the first few days of September, but after that time a severe drought set in, which lasted until about November 1. During the first week of November, fairly heavy rains fell throughout most of the area and with warm temperatures prevailing, there was a tendency for the trees to renew activity. Although there is no definite evidence of cambial activity, secondary thickening was no doubt still taking place in the entire trunks of young trees and on older trees the tissues in the crotches of the branches and near the bases of the trunks were in a very sensitive condition.

The trees had no chance to harden off. Up to November 14 no frost occurred excepting in certain very restricted areas in South Georgia and Western Florida. On the night of November 14–15, and again during the succeeding night, the temperature dropped sharply. Minimum orchard temperatures of 17 degrees F in St. Helena Parish, Louisiana, 15 degrees F in a rather low spot in Washington Parish, Louisiana, and 19 degrees F at the Experimental Tung Field in Pearl River County, Mississippi were recorded. The following night the temperatures at each of these points were higher, but in the eastern part of the tung belt the second night was the colder of the two. In Grady County, Georgia, 24 degrees F was recorded and in Levy and Alachua Counties, Florida temperatures ranged from 12 degrees F in one orchard to 20 degrees F in another. These are the *lowest temperatures recorded for the entire winter* at the respective points listed. The rate of fall and duration of the low temperature for three typical locations are shown in Fig. 1.

The immediate effect of the cold was to cause the leaves to drop. By noon of the first day all trees were practically denuded. Soon the tips of vigorous nursery trees wilted and shriveled. It was evident that much damage had occurred and plans were laid to make observations at regular intervals. The injury can be rather readily classified into well known types, and this paper will deal with the occurrence and degree of severity of each of these.

SEVERE KILLING BACK

Complete killing or very severe killing back of the trees was most common in the nursery and in young orchards but occurred also in orchards of mature trees. At the Experimental Tung Field Station in Pearl River County, Mississippi, rather detailed observations were

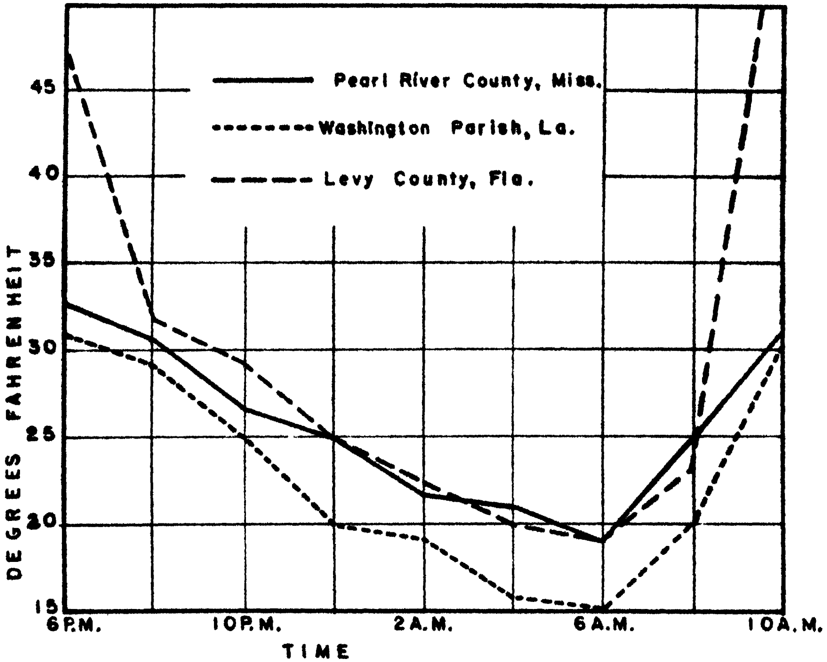

FIG. 1. Typical temperature trends in tung orchards in the southern United States during cold wave of November 1940.

made on approximately 10,000 budded nursery trees. These had been budded in the spring of 1940 on 1-year-old seedlings, and the tops had been cut back about 2 weeks later, forcing the buds into vigorous growth. Most of the trees were 5 to 7 feet tall. Severe killing back of the tops occurred throughout the entire block.

It is customary to cut tung trees back to a height of about 12 inches when transplanting from the nursery to the orchard. Consequently the injury to the base of the tree is of greatest importance. Therefore the 10,000 budded trees were classified according to the condition of the basal 12 inches of the trunks into three groups showing: 1, very slight, if any, discoloration of the tissues; 2, definite discoloration in the cortex, cambium and young xylem; and 3, all tissues killed. Fifty-eight per cent of the trees were found to be in group 1, 31 per cent in group 2 and 11 per cent in group 3. The trees of group 1 were transplanted to orchards in various parts of the tung belt, where nearly all of them grew satisfactorily. The injured trees were left in the nursery, where the majority of them made a rather remarkable recovery. Buds were forced from near the base of the trunk, new wood was quickly laid down and growth proceeded almost as rapidly as if they had not been injured.

Since budding of tung trees is a comparatively new practice, there is considerable interest in the relative hardiness of budded and seedling trees. At one farm in St. Helena Parish, Louisiana, a small block of seedlings suffered less than an adjoining block of budded trees. In a comparable location at the Experimental Tung Field Station, young trees from seed planted in February 1940 suffered rather more severely than the budded block. These seedlings were younger, smaller and not so mature as the budded trees. Two-year-old seedlings in a nursery on lower ground suffered less than the budded block, although no doubt they were subjected to a lower minimum temperature. However, these trees were not comparable in that they had not been cut back in the spring as were the budded trees. Perhaps the most accurate comparison can be made in a field in which about 1,000 trees budded in the fall of 1939 were set out in the spring of 1940 before the buds had been forced. An equal number of seedlings were set in the same field. At planting time, seedlings and budded trees were both cut back to the same extent. There was no opportunity to take accurate records in this field but general observations indicate that there was little difference between the two in degree of injury.

In the last analysis, the comparative hardiness of budded and seedling trees depends largely on the particular clone and the parentage of the seedlings being compared. In the budded block at the Experimental Tung Field Station, only 10 out of a total of 746 trees of the clone M-1 were injured, yet 553 out of 666 trees of the clone M-2 were either killed or seriously injured. Records of injury to trees grown from open pollinated seed of individual trees indicate that the progeny of some trees are much hardier than that of others. A considerable number of trees of each of 20 such progenies were rated in each of two orchards, which are about 25 miles apart. The ratings in one orchard show a correlation of +.490 to the ratings of the same progenies in the other orchard. This indicates that the differences observed are to a considerable extent inherent within the individual progeny, rather than being due to environmental factors.

Trees that had been planted in the orchard in the spring of 1940 suffered severely throughout the tung belt. In many orchards the majority of the trees were killed to the ground level. Injury to the tops of those not killed back completely was so severe that growers were advised to cut back all the trees to near the ground level and force them to make a fresh start. As a rule good results were obtained by cutting back in early spring. Fig. 2 shows such an orchard as it appeared the following October. In most orchards, however, the stand was by no means perfect. Sometimes as many as 30 to 40 per cent of the trees either failed to grow at all or made such weak growth that they will have to be replaced another season. Ordinarily the tung tree suckers very freely. Since the soil did not freeze, the failure of these trees to grow could not have been due to cold injury to the roots; hence it would appear that substances injurious to the roots were translocated downward from tissues injured by the cold or the roots contained too little reserve food to produce suckers.

Two-year-old tung orchards suffered considerably but as a rule less than 40 per cent of the trees were killed or so severely injured as to require cutting back. In 3-year-old orchards the injury was less than in younger ones and the mortality of trees of bearing age in most

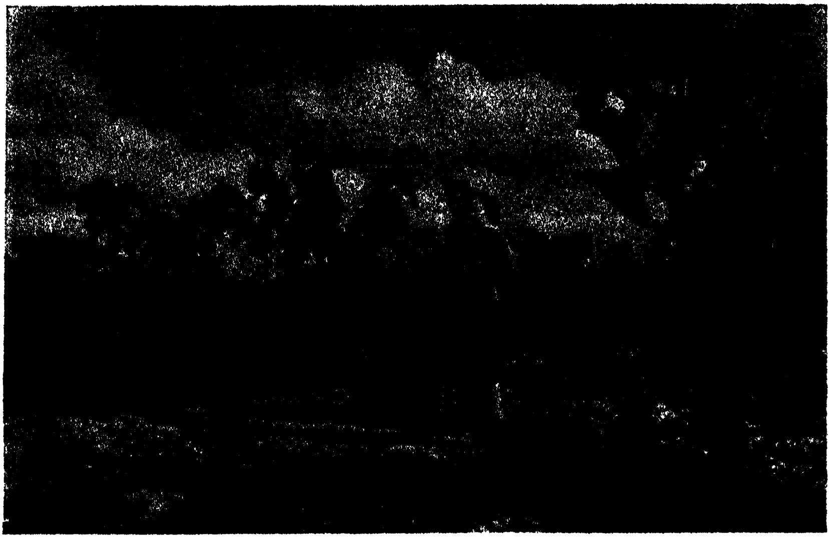

FIG. 2. Tung trees planted February 1940, killed back severely the following November, cut back to 12 inches in March, and photographed October, 1941.

sections was rather low. However, in one orchard in Florida, which is located in a rather low and cold area, entire blocks of mature trees were killed.

Little could be learned concerning the effect of factors other than temperature on the extent of injury. It is clear that those trees that had borne most heavily the previous year were most susceptible to the cold. Trees on light soil may have suffered more severely than those on heavy soil. At Ocala, Florida, extensive 3-year-old orchards, growing on light Norfolk sand, were practically destroyed. However, the evidence is not conclusive that this injury, unusually severe for 3-year-old trees, can be attributed to the soil type.

BUD AND TWIG KILLING

The tung tree produces a considerable number of pistillate and staminate blossoms in each terminal bud. By November these flower buds have reached a rather advanced stage of development. To determine the extent of bud injury, random samples of twigs from a considerable number of orchards were examined during December. The technique used was to split the bud and twig longitudinally, count the number of live and of dead flower buds visible under a binocular dissecting microscope and note the condition of the tissues near the tip of the twigs. It was found that the type of injury of most general occurrence was a killing of the pith cells at the tip of the twig. The dead cells shriveled and caused large cracks to appear in the pith (Fig. 3). Less frequently the tissues of the cambium and cortex were injured or killed outright. Twigs girdled with dead tissue sometimes had living flower buds. On the other hand part or all of the buds were sometimes dead on twigs uninjured in the cortex, phloem, and cambium. The proportion of twigs upon which, because of one or the other type of injury, no bloom could occur in the spring of 1941, ranged from practically zero in Grady County, Georgia, to more than 90 per cent in some parts of Alachua County, Florida. The average for about 1,500 twigs gathered from various parts of the tung belt, was 16 per cent. On the basis of these observations it was predicted in December that if no further frost damage occurred, the tung orchards would have a reasonably good bloom and produce a fair crop in 1941. This has proved to be true.

When the samples were taken in December, only one, or at most two twigs were taken from a single tree. It was not possible from these data, to determine whether the buds on some trees had fared better than on others. At blossom time in the spring it was found that all or nearly all of the twigs on some trees were dead. On others little or no injury occurred. For instance, on the original M-1 tree at McNeil, Mississippi, not a single blossom appeared to be killed. This tree bore a full crop this season.

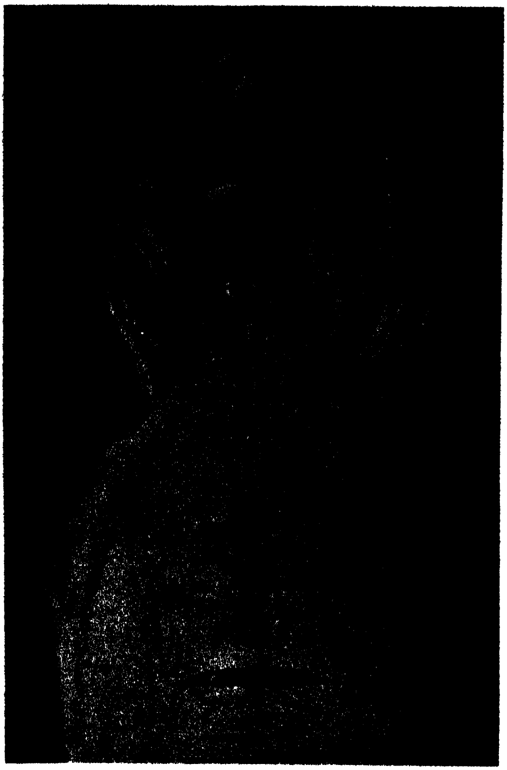

FIG. 3. Tip of tung twig showing pith injured by low temperature. (Photograph by L. P. McCann.)

CROTCH INJURY

Typical crotch injury was common, especially in young trees. The injured areas were largely confined to the trunks and did not extend any great distance up the branches. Often when the injury was severe and the branches close together, the whole trunk was girdled. In visiting orchards one would see hundreds of trees which, judging from experience with apples and other deciduous fruits, could not be expected to recover. However, as the season progressed, callus tissue rapidly filled in the injured areas and in many cases healing was complete at the close of the first growing season. For example, a 3-year-old tree in an orchard in St. Tammany Parish, Louisiana, had crotch cankers above two branches. In each case the area of dead tissue was about 7 centimeters wide by 3 centimeters high. By July 29 one crotch was almost completely healed and in the other the wound remained 2 centimeters wide by 1½ centimeters high. On November 13 both crotches were completely healed.

ISLANDS OF INJURY ON THE TRUNK

Frequently isolated spots and vertical strips of dead tissue were found on the trunks of the tree. Unlike the so-called "southwest injury", these injured areas occurred on any or all sides of the tree. These islands of injury varied from small spots, perhaps 2 to 3 centimeters wide by 5 centimeters high, up to areas that nearly encircled the trunk, leaving only a narrow strip of living tissue on one side.

Trees affected with this type of injury leafed out and in most cases a rather remarkable recovery took place. Healing proceeded from either edge of the wound toward the center and in some cases injuries 3 to 5 centimeters wide were completely healed by the end of the first growing season. Areas that were originally very large were only partially healed, and some trees with such injury have become weakened by wood rot and have been broken over.

COLLAR ROT

A few cases of typical collar rot were found, in which the trunks were completely girdled with dead tissue just at the surface of the soil. These trees leafed out and set fruit but the foliage soon turned yellow and death resulted before the close of the season. More frequently trees were found that had been completely girdled with dead tissue at a little distance above the surface of the soil, but without injury to the upper part of the trunk and branches. These trees leafed out and sometimes set fruit but eventually wilted and died. Suckers starting from the lower part of the trunks early in the season made these trees conspicuous. Where this occurred on trees not over 2 or 3 years of age, the suckers were sometimes used to make a new tree. Such trees have an exceedingly large scar to heal over at the base and if nursery trees were available it would probably be best to replant.

SUMMARY

In summing up the situation, it may be said that the very cold weather coming before the tung trees were dormant caused severe injury, but that the trees have made a remarkable recovery during the first growing season.

Leaf Sap Concentration and Cold Resistance in the Avocado

By F. F. HALMA, *University of California, Los Angeles, Calif.*

HARRIS and Popenoe (2) reported in 1916 that the leaf sap of avocado varieties belonging to the West Indian race was less concentrated than that of varieties belonging to the Guatemalan and Mexican races. These results, they pointed out, agree with horticultural experience in that the West Indian avocado is less resistant to cold than the other two races. They found, however, no consistent differences in the freezing point depression between the leaf sap of the Guatemalan and Mexican races, although varieties of the latter are much more resistant to cold than varieties of the former. Moreover, there are varietal differences in cold resistance within all three races.

Harris and Popenoe were aware of the complexity of the problem, but thought it highly probable that a thorough knowledge of the freezing point lowering of leaf sap would be of some service in predicting ability to withstand cold. This report deals with an attempt to explore this probability.

All commercial varieties in California belong to the Guatemalan or Mexican races; a third group whose members have characters intermediate between the two are referred to as hybrids. The most important variety in California, the Fuerte, belongs to the latter. Varieties of the West Indian race are unsuited climatically to California conditions.

As to the botanical classification there is disagreement. Some botanists place the West Indian and Guatemalan under one species, *Persea americana, Mill.*, and the Mexican under another species, *P. drymifolia, Cham. & Schlecht,* while others refer to all three races as *P. americana.* The latter view is shared by Popenoe (4) who believes that there are insufficient grounds for separating the three races botanically.

MATERIALS AND METHODS

In general the procedure was the same as that previously followed for citrus by Halma (1) which in turn was based on Walter's recommendation (5). At 2 weeks intervals between May, 1938 and April, 1940, the osmotic value (Ov) and the per cent of total soluble solids of the leaf sap were determined for the following varieties: Mexican race — Puebla, Mexicola, Duke, and Topa Topa; Guatemalan race — Nabal, Dickinson, and Benik; Hybrid — Fuerte. These varieties are growing in the orchard at the University of California, Los Angeles. All were of bearing age but their bearing behavior differs, some fruiting yearly and others irregularly. All are on Mexican seedling rootstock.

Care and experience are essential in the collection of the leaves. The time of the day, location on the tree, condition and age of leaf are factors which affect the sap concentration. For this reason leaves of comparable age were gathered between 7:45 and 8:15 a.m. from the west side of the tree which, at that time of day, had not received direct sunshine. A sample consisted of from two to four leaves, depending upon their size. They were wrapped immediately in damp cloth to prevent water loss. The green weight of the samples ranged from 8 to 14 grams, and the amount of sap obtained from the killed leaves varied from 3 to 5 cubic centimeters. After removing surface moisture and dust each sample was placed in a vial 108 millimeters in height, 27 millimeters in diameter, capacity of 40 milliliters, and provided with a black, molded screw cap. A rubber washer (cut from a discarded automobile inner tube) was placed inside the cap to provide an air-tight fit.

The leaves were killed with heat by placing the vials in a covered vessel which contained sufficient water to cover the vials to the lower edge of the screw cap. The water was heated before immersing the vials and then brought to a boil rapidly. The leaves were kept in this atmosphere of boiling water for 30 minutes, then taken out and allowed to cool for at least 3 hours before making the determination. As previously pointed out by Walter (5), Mallory (3), and Halma (1), the main advantage of killing leaves by heat is that they can be stored without significantly affecting the Ov of the sap. Leaves killed by cold are unstable, thus if avocado leaves are killed by cold (solid carbon dioxide), their Ov may increase from 2 atmospheres after a 3-hour storage at room temperature (between 70 and 80 degrees F) to 5 atmospheres after 72 hours. This change is less rapid when the leaves are kept at 40 degrees F. If killed by heat, the Ov of the sap of comparable leaves may show a plus or minus variation of 1 atmosphere.

Each sample, wrapped in a piece of strong muslin cloth 10 square centimeters, was placed between two steel plates held by a 6-inch vise. By gradual increase in pressure a good extraction was obtained. No tests as to the effect of pressure on the Ov were made, but on the basis of previous investigation with citrus (1), it was assumed that the avocado behaves similarly; namely, that with small samples there is no consistent difference between the Ov of the sap obtained with a 9000 pounds per inch pressure and the Ov of sap obtained with a 6-inch vise.

The freezing point was determined with a Drucker-Burian microthermometer. This thermometer has a fixed scale ranging from 0.5 to —5.5 degrees C in divisions of 0.02 degrees. The entire length of the thermometer is only 28 centimeters. The mercury column cannot be set for various ranges in temperature depressions as it can be in the Beckmann thermometer. With an ordinary hand lens the temperature can be read to 0.01 degree C, which is sufficiently accurate for plant material. The thermometer scale is too short to determine the total amount of undercooling; hence it is necessary to arrest the undercooling by quickly introducing and withdrawing a glass capillary or a piece of platinum wire containing particles of frozen distilled water and then stirring the sap rapidly.

The brine temperature was kept between —8 and —10 degrees C. 2 cubic centimeters of sap were used which allowed complete immersion of the thermometer bulb without touching the bottom of the tube. The undercooling was arrested at approximately 1 degree below the actual freezing point of the sap. The values obtained were translated into atmospheres.

An additional index of the physico-chemical characteristics was obtained by determining the per cent of the total soluble solids by means of a refractometer.

DISCUSSION OF THE DATA

Before discussing the data it is necessary to refer briefly to the relative cold hardiness of the eight varieties included in this investigation. On the basis of observations made after the severe freeze of January, 1937, the range in cold hardiness is about 10 degrees F with Duke, and probably Mexicola, the hardiest, and Benik the least hardy. The range in hardiness among members of the Mexican race is greater than that among Guatemalan varieties. Thus the difference between Duke and Puebla is about 7 degrees F. Topa Topa, one of the Mexican varieties, needs special mention. Information concerning it and Mexicola are meagre due to the fact that they are used only for rootstock purposes. While there is little doubt concerning Mexicola, the status of Topa Topa is not certain. It was considered very hardy until one observer reported after the 1937 freeze that a tree of this variety suffered as much injury as an adjacent Puebla.

Puebla and Fuerte, the

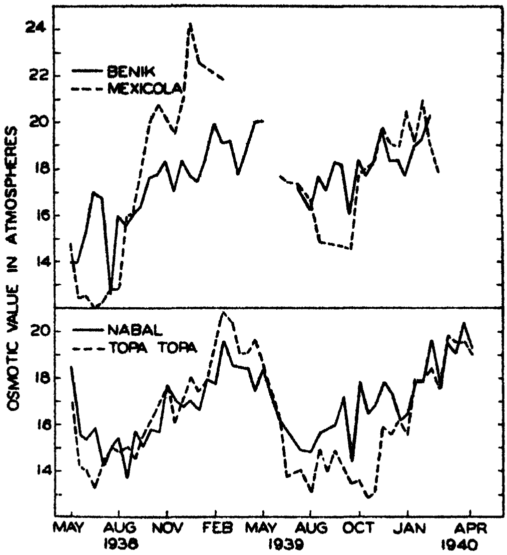

FIG. 1. Osmotic value of leaf sap.

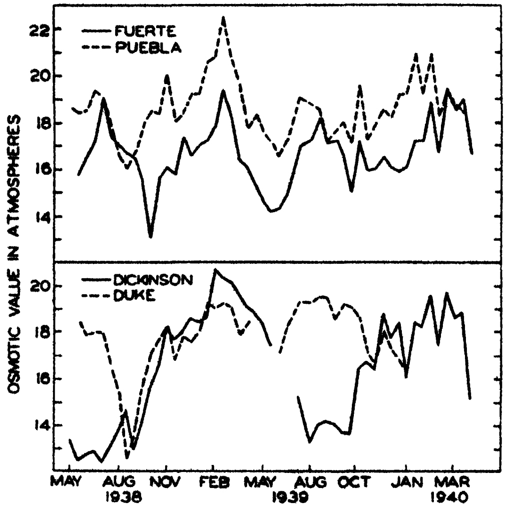

FIG. 2. Osmotic value of leaf sap.

latter considered a Mexican-Guatemalan hybrid, are about equal in hardiness. The range between these two varieties on the one hand, and the three Guatemalan on the other, probably does not exceed 4 degrees F. Nabal seems to be slightly hardier than Dickinson, but Benik is definitely the most tender.

Assuming the existence of a relationship between cold hardiness and leaf sap concentration, as implied by Harris and Popenoe, one should find a higher Ov for a hardy variety like Duke than for a relatively tender one like Benik. However, the data do not support this assumption. In each graph (Figs. 1 and 2) a Mexican variety is compared with a Guatemalan, except in one case where Fuerte is compared with Puebla. The gaps in the graphs for Duke, Mexicola, Dickinson, and Benik are due to lack of suitable leaves; it seems that leaves of these varieties are shorter lived than those of the others used in this investigation.

Attention should be focused on the period between November and March when low temperatures are most likely to occur. The graphs indicate that during this period there is no consistent relationship between cold hardiness and Ov. Thus, during the 1938–39 winter the Ov for Mexicola is higher than that for Benik, but the values during the following season are practically the same. Dickinson, which is relatively tender, shows values similar to those of the hardy Duke, and there is practically no difference between Nabal and Topa Topa. Finally it should be noted that Puebla values are higher than those for Fuerte

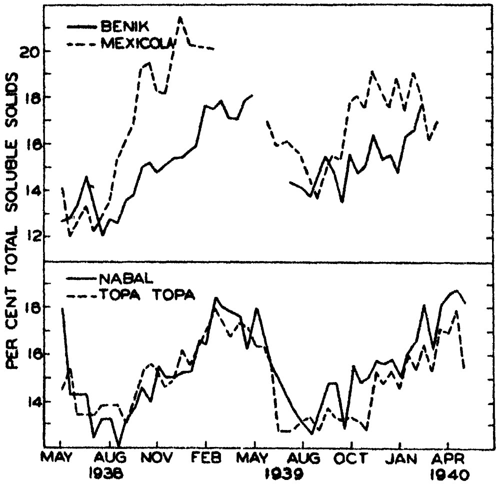

FIG. 3. Per cent of total soluble solids of leaf sap.

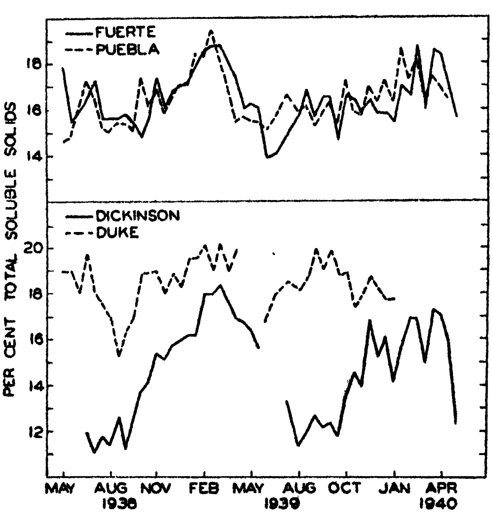

FIG. 4. Per cent of total soluble solids of leaf sap.

during both seasons, a condition which does not agree with the observed similarity in hardiness of the two varieties.

The percentages of total soluble solids (Figs. 3 and 4) are suggestive. With only one exception, Topa Topa, the values are higher for the hardy varieties than those for the relatively tender ones. The consistently higher values for Duke and Mexicola as compared to Dickinson and Benik, together with the similarity in values between Puebla and Fuerte, are in accordance with field observations on cold hardiness.

CONCLUSION

Leaf sap concentration studies of eight Avocado varieties covering a period of 2 years, revealed no relationship between the osmotic value of expressed leaf sap and cold hardiness. Percentage of total soluble solids, however, were, in most cases, consistently higher for the hardy varieties than for the relatively tender ones.

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A Note on an Unusual Case of Cold Injury to The Haralson Apple

By W. G. BRIERLEY, *University of Minnesota, St. Paul, Minn.*

THE Haralson apple has made a place for itself in Minnesota and other northern localities partly because of its ability to endure low winter temperatures. Sometimes, however, under unusual conditions, injuries to this variety have been noted, such as in the following case.

At the University of Minnesota Fruit Breeding Farm, a 10-year-old orchard located on a gently rolling site includes a fairly large block of Haralson trees. It is believed that the maturity of these trees had been advanced to some extent by drouth during September, 1940 when only ½ inch of rainfall was recorded. Temperatures throughout October were relatively high and there was no frost. Light to moderate frosts occurred during the first 10 days of November, the lowest temperature being 26 degrees F. This mild weather was followed by the blizzard of November 11, 1940 during which snow drifted shoulder high through a part of the orchard and covered the lower branches of a dozen or more of the Haralson trees. During this storm the temperature fell rapidly to 5 degrees F and for the next 5 days the minimum temperatures were close to zero.

As the early and subsequent snowfalls settled, the lower scaffold branches were bent down and many were badly split at the crotch. When the mechanical injury was observed in early January, an attempt was made to avoid further damage by removing the load of snow and lifting the branches. Those that were dug from the snow were subjected to a drop in temperature within 2 or 3 hours from approximately 25 degrees to 30 degrees in the snow to an air temperature varying from zero to —10 degrees F. Some branches were overlooked and remained under the snow all winter.

By the end of the following May, it was evident that there was a marked difference in the conditions of the branches that had been covered by snow. Those that had been lifted from the snow were completely killed. Those from which the snow had not been removed developed good foliage and set a fairly heavy crop. The tops of the trees that had been above the snow throughout the winter showed no injury and also set a heavy crop in 1941.

From a study of these cases and of the snow and temperature conditions, it appeared very probable that although the upper branches of these trees went through the usual hardening process, the branches covered by snow, were not fully hardened. It appears likely that these not fully hardened branches were not able to endure the sudden and severe drop in temperature. The branches that were left beneath the snow were not exposed to severe low temperatures and escaped injury except for breakage as noted. The upper branches that were fully hardened were able to endure exposure to sub-zero temperatures and also escaped injury.

Apple Breeding: Variation Within and Between Progenies of Delicious with Respect to Freezing Injury Due to the November Freeze of 1940[1]

By H. L. LANTZ and B. S. PICKETT, *Iowa Agricultural Experiment Station, Ames, Ia.*

THE wide-spread damage to the fruit industry of the Missouri River Valley region caused by the November freeze of 1940 is described elsewhere in this volume by Maney.

A number of reports have shown differential killing of trees in crossbred apple progenies due to low winter temperatures but killing due to out-of-season freezes is comparatively rare and there are no records in Iowa to indicate comparable damage from any other out-of-season freeze such as occurred in November of 1940. Some damage was sustained in orchard trees by a similar freeze in late October of 1925, but the killing of entire trees or orchards was not extensive, although nursery stock was very severely injured or killed at that time. Whether an out-of-season freeze such as occurred in November 1940, provides a reliable index to hardiness in varieties or seedlings may be debatable but the fact remains that varieties long regarded as hardy were less injured than the well known semi-hardy varieties. There are exceptions but the exceptions do not seem sufficiently important to invalidate studies dealing with relative hardiness.

Because of the extensive injury and killing of trees of commercial varieties it was of particular interest to study and record the behavior of the crossbred apple seedlings growing in the station orchards at Ames. An examination of all the seedling trees was made in October 1941. Data relative to the behavior of the trees of 24 crossbred progenies of Delicious form the basis of this report.

METHOD

Each seedling tree was examined to determine the extent of the injury sustained in the (a) trunk, (b) crotches and large limbs, and (c) twigs; and an over-all judgment evaluation (d) which took into account trunk, branch and top injury was made of each tree in order to secure a summation estimate of the condition of each tree at the end of the 1941 growing season.

TRUNK INJURY

The amount of bark killing varied from fractional to complete encirclement of the trunk. The bark area extending up the trunk from about 2 inches above the ground line on the west and southwest sides of the trunks was most severely damaged. Bark that remained alive on partially injured trees was practically always found on the east and northeast sections of the trunk. The amount of bark killing on the trunks was classified arbitrarily as follows: 0, free of injury; 1, first degree injury not exceeding one-fourth of circumference; 2, second degree injury not exceeding one-half of circumference; and 3, third degree injury exceeding one-half of circumference. Crotch and large limb damage was recorded on a similar scale. Twig damage was recorded on a basis of estimates as to the amount of twigs killed and was recorded on a similar scale. In order to arrive at an estimate as to the future usefulness of each tree, a summation estimate of the damage to trunks, crotches, limbs and twigs was considered along with the quality and amount of growth made during 1941. Generally trees with no injury or with only first degree injury to the trunk, limbs and tops were regarded as having future value. Trees with second and third degree injury were regarded as having little permanent recovery value. A number of trees were dead and were so recorded.

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[1] Journal Paper No. J-957 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project 284.

In cooperation with the Bureau of Plant Industry, United States Department of Agriculture.

MATERIALS

Data derived from an examination of the trees of 24 progenies of Delicious are the basis of this report. A total of 1,603 trees were involved. The trees ranged in age from 12 to 17 years. The progenies ranged from 11 to 241 in number of trees. Seventeen of the progenies contained 30 or more trees. The trees were originally planted 8¼ by 16½ feet apart, but in most of the progenies a number of trees had been pulled prior to 1940, following their fruiting, so that the total number of trees now in the orchard, particularly in the 1924 and 1925 plantings, has been considerably reduced as compared with the original plantings. This situation should not disturb the significance of these data.

PROGENY HARDINESS INDEX

In order to calculate the mean hardiness of these Delicious progenies, an arbitrary code was used. The data relating to the general condition of the trees were used to calculate the mean hardiness index of these Delicious progenies.

The trees falling into the various categories of survival or injury were coded as 10, 7, 4, and 1, with 10 denoting those trees that were either free of injury or so slightly injured that they showed evidence of making a normal recovery. Trees classified as having suffered first degree injury were coded at 7; those which suffered second degree injury were coded at 4; and those suffering third degree injury were coded at 1. Dead trees and those with very little live wood were rated at 0. The mean hardiness, index "I", of each of the 24 progenies was calculated by dividing the sum "S" by the number of trees in the progeny. The sum "S" was found by summating the products secured by multiplying the code number by the number of trees falling into the various categories. Since the progenies of Delicious here studied have shown marked variation in their ability to resist winter killing such as occurred in November of 1940, it was deemed sufficient to present these data without further statistical treatment. The data indicate what crosses produced trees having a relatively high "I" and what parent varieties in combination with Delicious can be depended upon to produce a relatively high percentage of hardy trees.

The mean hardiness index is a useful statistic for comparing progenies. The distribution of the trees which fell into the various categories of survival or relative amounts of injury is instructive but does not lend itself to genetic interpretations, since the physical evidences of injury are not plant characters. The data, however, present a picture of the hardiness relationships within and between the progenies and provide tangible evidences that apple varieties differ significantly in their genetic constitutions. Certain varieties produced a high percentage of hardy seedlings and certain other varieties produced a low percentage of hardy seedlings. The information derived in this study confirms previous conceptions as to the inheritance of hardiness.

The 1,603 trees of 24 progenies of Delicious were found to have a mean hardiness index of 6.7. An examination of Table I shows clearly the wide differences between the various crosses. Several progenies are small and possibly the calculated "I" does not represent the true mean. Progenies containing 25 to 30 trees are large enough to yield a fairly reliable estimate of their mean hardiness.

TABLE I—DELICIOUS PROGENIES, GENERAL CONDITION OF TREES, MEAN HARDINESS INDEX "I"

Parentage	No. of Trees	General Condition (October 15, 1941)					
		10*	7	4	1	0	"I"
Wealthy × Delicious	81	70	2	6	2	1	9.13
Patten Greening × Delicious	74	63	6	3	2	—	9.27
Antonovka × Delicious	183	152	11	10	10	—	9.00
Northwestern Greening × Delicious	81	42	8	12	13	6	6.66
Anisim × Delicious	154	71	16	32	32	3	6.44
Fameuse × Delicious	30	11	1	5	13	—	5.00
Jonathan × Delicious	241	70	33	52	59	27	4.97
Pewaukee × Delicious	26	7	2	9	8	—	4.91
Malinda × Delicious	13	3	1	3	5	1	4.15
Northern Spy × Delicious	158	28	13	41	53	23	3.72
Delicious × Jonathan	44	5	5	10	19	5	3.27
Ames 503 × Delicious	80	55	8	9	6	2	8.01
Sharon × Delicious	83	56	9	9	8	1	8.03
Ames 524 × Delicious	38	19	11	5	1	2	7.95
Edgewood × Delicious	11	5	2	2	2	—	6.73
Monona × Delicious	26	10	2	6	7	1	5.58
Ames 516 × Delicious	17	4	2	6	4	1	4.82
Patten 1001 × Delicious	50	41	1	6	1	1	8.84
Patten 1031 × Delicious	59	47	3	8	1	—	8.92
Patten 1000 × Delicious	19	14	1	2	2	—	8.26
Patten 1015 × Delicious	37	19	6	8	4	—	7.25
Patten 1003 × Delicious	17	12	3	2	—	—	8.76
Patten 1037 × Delicious	41	12	8	14	7	—	5.83
Patten 1011 × Delicious	40	10	10	8	6	6	5.20
24 progenies of Delicious	1603	826	164	268	265	80	6.70

*General tree condition:
10 = None or slight.
7 = 1st degree injury.
4 = 2nd degree injury.
1 = 3rd degree injury.
0 = Dead or nearly so.

The mean hardiness index "I" shows some very interesting groupings of parent varieties. For example, the large progenies of Patten Greening x Delicious, Antonovka x Delicious and Wealthy x Delicious have a remarkably close mean hardiness index "I". This suggests that the Patten, Antonovka and Wealthy carry similar doses of those major factors which produce a high percentage of relatively hardy trees. A similar situation is shown by the grouping of Delicious crosses involving Anisim, Northwestern Greening and Edgewood. Further down on the index scale another grouping of varieties occurs with the Delicious progenies of Fameuse, Pewaukee and Jonathan falling close together. The reciprocal crosses of Jonathan x Delicious show a markedly different hardiness index.

Many crosses have been made from time to time on seedlings of known parentage. In the case of Sharon (McIntosh x Longfield) x Delicious the mean hardiness index is close to 8. The "I" for the progenies, Ames 503 (Harrington x Ralls 18) x Delicious and Ames 524 (Wealthy x Colorado Orange) x Delicious, was also close to 8. In the case of selected seedlings of the Patten series, 5 of the 7 progenies had an "I" well above the mean of the 24 progenies of Delicious. These seedlings were used as parents because of their desirable fruit and tree characteristics. Their behavior under the conditions of the November freeze indicates that their use was justified and suggests that carefully selected seedlings may have considerable future significance in the breeding program.

In nearly all, if not all, of these progenies of Delicious, trees were often found which were free of freezing injury. In the Middlewest, trees of the varieties Jonathan and Delicious were almost without exception damaged severely and thousands were killed outright; yet some of the trees produced by the cross Jonathan x Delicious, showed little or no evidence of freezing damage. The fact that some trees in nearly all crosses were found free of injury and that the trees in each of the progenies showed varying degrees of freezing damage clearly indicates that hardiness is conditioned by a complex situation; and that the multiple factor hypothesis must be relied upon to explain the range of hardiness found in these Delicious progenies. It appears evident that the different parent varieties used in these Delicious crosses differ widely in their genetic constitution and transmit to their progenies factors for hardiness on a basis which results in the production of trees having varying degrees of hardiness. This is substantiated by the fact that in most of the progenies all degrees of resistance to freezing injury, ranging from no injury to complete killing, were observed. The significant fact is that certain hardy varieties, when crossed with Delicious, produced progenies in which a high percentage of the trees were either free from injury or suffered little damage due to the freeze. By comparison, Delicious when crossed with tender varieties produced a high percentage of trees which suffered serious injury. Two general facts seem apparent: (a) Hardy varieties transmit their hardiness to a relatively high percentage of trees, even when crossed with a tender variety like Delicious; and (b) a portion of the seedling trees produced by crossing two tender varieties may be hardier than either parent.

An Analysis of the Fruit Characteristics of Seedlings of Rome Beauty, Gallia Beauty, and Golden Delicious Parentage

By Fred O. Hartman, *Ohio State University, Columbus, Ohio,*
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AN APPLE variety is desired for Ohio which will have the characteristics of late blooming, late keeping, and high dessert quality, and also will be relatively resistant to scab, bitter pit, and other physiological disorders. A portion of the breeding work undertaken in order to obtain a variety with the above characteristics furnished the data for this analysis.

The progenies analyzed originated from: (a) Rome Beauty self-pollinated; (b) Gallia Beauty self pollinated; (c) Rome Beauty x Gallia Beauty and the reciprocal cross; (d) Rome Beauty x Golden Delicious; and (e) Gallia Beauty x Golden Delicious.

The fruit descriptions were made during the years 1929 to 1941 at the Ohio Agricultural Experiment Station at Wooster. The characteristics analyzed are blooming date of the seedlings, and the color, size, quality, storage season, and picking.date of the fruits obtained therefrom. The data presented indicate to some extent: (a) the inheritance of six characteristics, and (b) the genetic makeup of the parents.

Results

Blooming Date:—Rome Beauty and Gallia Beauty are late blooming varieties. The average date of first bloom at Wooster is May 7. Golden Delicious is a day earlier. The data for blooming dates revealed that in four of the six progenies there were no seedlings which bloomed before their parents. In the progenies from Gallia Beauty selfed and Gallia Beauty x Rome Beauty a small percentage of the seedlings bloomed 1 day before the parents. A large percentage of the seedlings bloomed after the parent varieties. Rome Beauty and Gallia Beauty are apparently heterozygous for blooming date since the progenies showed a range in blooming dates from 1 day before to 11 days after the parents; a spread which suggests that a number of cumulative genes are concerned.

Color:—Both Rome Beauty and Gallia Beauty are highly colored apples, Gallia Beauty being the better colored. According to the classification used herein, Rome Beauty and Gallia Beauty are placed in the class for 50 per cent or more of the surface colored. Gallia Beauty, which is more highly colored than Rome Beauty, comes close to being classified as having a solid overcolor.

Table I reveals that the progeny of Rome Beauty self-pollinated produced a considerably smaller percentage of seedlings with fruit having a solid overcolor and a corresponding higher percentage with no overcolor than did Gallia Beauty self-pollinated. Rome Beauty x Gallia Beauty and the reciprocal cross showed a small difference in color inheritance. Approximately 30 per cent of the seedlings from

TABLE I—DISTRIBUTION OF COLOR OF SEEDLING FRUITS FROM SIX PROGENIES

Parentage	Number of Seedlings	Complete or Solid Color (Per Cent)	50 Per Cent or More Colored	Less Than 50 Per Cent Colored	Blush or No Overcolor (Per Cent)
Rome Beauty selfed	46	2.2	43.5	19.5	34.8
Gallia Beauty selfed	31	22.6	51.6	6.4	19.4
Rome Beauty ×Gallia Beauty	10	10.0	60.0	20.0	10.0
Gallia Beauty ×Rome Beauty	27	22.2	48.2	14.8	14.8
Rome Beauty ×Golden Delicious	50	0	44.0	14.0	42.0
Gallia Beauty ×Golden Delicious	37	32.4	18.9	0	48.7

both crosses had fruits with less than 50 per cent surface color. In the crosses with Golden Delicious, a yellow apple, Rome Beauty produced no seedlings having fruit with solid overcolor, whereas Gallia Beauty gave 32 per cent of fruits having solid overcolor. Both of these crosses gave a high percentage of fruits either with no overcolor or with a blush.

Thus the data in Table I indicate that Gallia Beauty carries more factors for highly colored fruit than does Rome Beauty. This substantiates the prevailing opinion that Gallia Beauty is a seedling rather than a mutation of Rome Beauty. Vincent and Longley (2) state that a high percentage of seedlings having Rome Beauty as one parent were of greenish color. This is substantiated by the results given herein. The data indicating the heterozygous (for red and yellow) makeup of Rome Beauty and Gallia Beauty for skin color confirm the statement of Crane and Lawrence (1) that inheritance and distribution of anthocyanin appears to be controlled by a number of genes.

Size:—Rome Beauty and Gallia Beauty fruits are generally recognized as being of medium to large size. The average is above medium. Rome Beauty selfed produced a somewhat higher percentage of seedlings with large sized fruit than did Gallia Beauty selfed. Rome Beauty x Gallia Beauty and the reciprocal cross showed some difference in the inheritance of the size characteristic. Rome Beauty x Golden Delicious producer a greater percentage of seedlings with fruit above medium in size than did Gallia Beauty x Golden Delicious.

In all of the progenies except one there were seedlings which produced fruit of small size. Wellington (3) states that Rome Beauty carries one or more factors for large and small fruits. The wide distribution in the size of the fruit of the progenies as seen in Table II substantiates this statement. The average size of the fruits of the

TABLE II—DISTRIBUTION OF SIZE OF SEEDLING FRUITS FROM SIX PROGENIES

Parentage	Number of Seedlings	Large (Per Cent)	Above Medium (Per Cent)	Medium (Per Cent)	Below Medium (Per Cent)	Small (Per Cent)
Rome Beauty selfed	46	15.2	17.4	45.6	10.9	10.9
Gallia Beauty selfed	31	9.7	19.3	45.2	12.9	12.9
Rome Beauty ×Gallia Beauty	10	20.0	20.0	50.0	10.0	0
Gallia Beauty ×Rome Beauty	27	7.4	22.2	48.2	7.4	14.8
Rome Beauty ×Golden Delicious	50	22.0	20.0	44.0	2.0	12.0
Gallia Beauty ×Golden Delicious	37	8.1	8.1	54.1	5.4	24.3

TABLE III—DISTRIBUTION OF QUALITY OF SEEDLING FRUITS FROM SIX PROGENIES

Parentage	Number of Seedlings	Good (Per Cent)	Fair (Per Cent)	Poor (Per Cent)
Rome Beauty selfed	46	4.4	30.4	65.2
Gallia Beauty selfed	31	0	35.5	64.5
Rome Beauty ×Gallia Beauty	10	0	40.0	60.0
Gallia Beauty ×Rome Beauty	27	0	44.4	55.6
Rome Beauty ×Golden Delicious	50	2.0	34.0	64.0
Gallia Beauty ×Golden Delicious	37	8.1	48.7	43.2

progenies is slightly below the fruit size of the parents.

Quality:—Rome Beauty and Gallia Beauty are considered fair in quality. Only a few of their seedlings produced fruits of good quality. These occurred in the progenies of Rome Beauty selfed, Rome Beauty x Golden Delicious, and Gallia Beauty x Golden Delicious where 4, 2, and 8 per cent respectively of the seedlings produced fruit of good quality. Table III shows that in all of the progenies there is a high percentage of seedlings with poor quality fruit. The fruits produced by Rome Beauty x Gallia Beauty and its reciprocal cross were similar in quality. The only progeny in which over 50 per cent of the seedlings produced fruit of good or fair quality was Gallia Beauty x Golden Delicious.

From the distribution of the progeny, it appears that Rome Beauty and Gallia Beauty are heterozygous for quality and possess polymeric genes for this characteristic.

Season:—Rome Beauty and Gallia Beauty are usually considered as keeping in common storage until January or February, and in cold storage until April. The data in Table IV show that Rome Beauty and Gallia Beauty produce progenies which have an average season about like that of the parents, namely, January. Gallia Beauty produced a somewhat higher percentage of seedlings having fruit with a late keeping season than did Rome Beauty.

TABLE IV—DISTRIBUTION OF SEASON OF SEEDLING FRUITS FROM SIX PROGENIES*

Parentage	Number of Seedlings	November (Per Cent)	December (Per Cent)	January (Per Cent)	February (Per Cent)	March or Later (Per Cent)
Rome Beauty selfed	46	0	15.2	43.5	19.6	21.7
Gallia Beauty selfed	31	3.2	12.9	32.3	25.8	25.8
Rome Beauty ×Gallia Beauty	11	9.1	36.3	27.3	18.2	9.1
Gallia Beauty ×Rome Beauty	27	7.4	33.3	18.5	22.2	18.5
Rome. Beauty ×Golden Delicious	50	0	26.0	40.0	24.0	10.0
Gallia Beauty ×Golden Delicious	37	0	2.7	43.2	32.4	21.6

*The figures in this table are the percentage of the seedlings whose fruit keeps in storage at 35 to 40 degrees F to the month designated.

The range in season shows that Rome Beauty and Gallia Beauty are heterozygous for this characteristic; and these data indicate that the inheritance of this characteristic is dependent upon the interaction of a number of complementary genes.

Picking Date:—The average picking date at Wooster, Ohio, for

Rome Beauty is October 26; for Gallia Beauty, October 23; and for Golden Delicious, October 19. In each of the progenies there was a considerable percentage of seedlings having a picking date earlier than the parents. This was 59 per cent in the case of Rome Beauty selfed and 69 per cent for Gallia Beauty selfed. The inheritance of this characteristic is undoubtedly dependent upon polymeric genes since the distribution of the picking dates of seedlings ranged from 8 weeks before to 4 weeks after the parents.

Conclusions and Summary

Rome Beauty and Gallia Beauty transmit factors for late blooming; no overcolor to solid overcolor; small to large fruit size; poor to good quality; early to late season in storage; and mid to late picking date.

Rome Beauty and Gallia Beauty transmit predominately the factors for late blooming, only fair color, poor quality, January season, medium size, and mid-October picking date.

The fruit characteristics of seedlings from the cross Rome Beauty x Gallia Beauty and its reciprocal are unlike in class distribution for the characteristics of size, color, and possibly season in storage.

The results obtained further substantiate the conclusion that Rome Beauty and Gallia Beauty have a heterozygous genetic constitution, and that a number of factors or genes both cumulative and differential govern the inheritance of the characteristics analyzed in this paper.

Rome Beauty and Gallia Beauty are deemed worthy of very limited use in future breeding work where good color and dessert quality is desired since they failed to transmit these characteristics to a satisfactory extent. Gallia Beauty is preferable in this particular.

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Further Observations on a Narrow-Leaf Variation of the Apple[1]

By A. P. French and Lawrence Southwick, *Massachusetts State College, Amherst, Mass.*

IN 1933, the senior author reported an unusual leaf variation on Red Astrachan (1). Subsequently a similar specimen of Baldwin and one of McIntosh were observed in commercial nurseries in New York. Both of these aberrant forms have been propagated and are now growing in the Experiment Station nursery.

In the summer of 1940, buds from narrow-leaf branches of each variety were set in the nursery. The buds were taken consecutively from the base to the tip of the shoot in each case. With Baldwin, from a total of 50 successful buds only two produced entirely normal Baldwin growth and three whips had both normal and abnormal parts. The normal growths on these trees always originated as laterals near the base of the whip. Fig. 1 shows the three types. Similar variations are common on McIntosh and Red Astrachan also. Fewer buds of these varieties were set, but on the basis of their performances in this and previous years it would seem that the narrow-leaf character is less constant than with the Baldwin. Sixteen McIntosh whips were abnormal, four only partly abnormal, and three entirely normal. With Red Astrachan, eight trees were of the variant type, three were mixed,

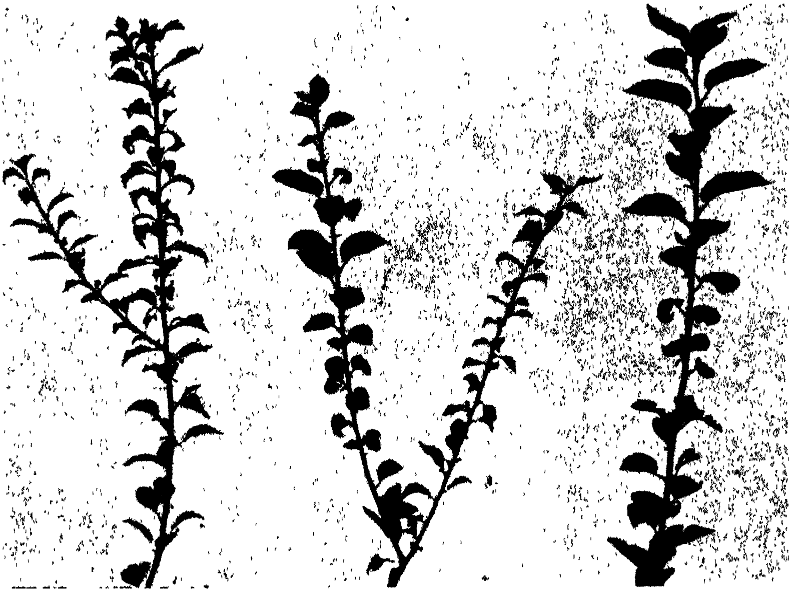

FIG. 1. One-year Baldwin trees showing narrow-leaf and normal types of growth. The center tree is abnormal with a vigorous normal lateral.

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[1] Contribution No. 425 of the Massachusetts Agricultural Experiment Station.

and six seemed entirely normal. These observations were made in September. Earlier in the growing season, fewer narrow-leaf trees showed normal branches, indicating the inconstancy of the abnormal tissue. Only with Red Astrachan did there seem to be a fairly good relationship between the narrow-leaf character and the leaf phyllotaxy.

The growth and leaf characteristics of the narrow-leaf trees vary with the variety. The relative height growth is similar to that of normal trees of the three varieties. The typical taller growth habit of Baldwin for example is not masked by this character. Although type of growth is quite similar in a general way, the abnormal form of each variety has certain individual characteristics. Red Astrachan tends to have extremely narrow and elongated leaves, especially near the short tips. The short internodes here give a typical rosette appearance. The abnormal Baldwin leaf is not so elongated and is more deeply serrated. Although there is a characteristic pose for each variety, there is no question regarding the fundamental similarity of these three variant forms. The shoot growth is slender and shorter than that of normal trees. The leaf types are much the same in being relatively thick, tough, and leathery. Leaves of the variant form are about

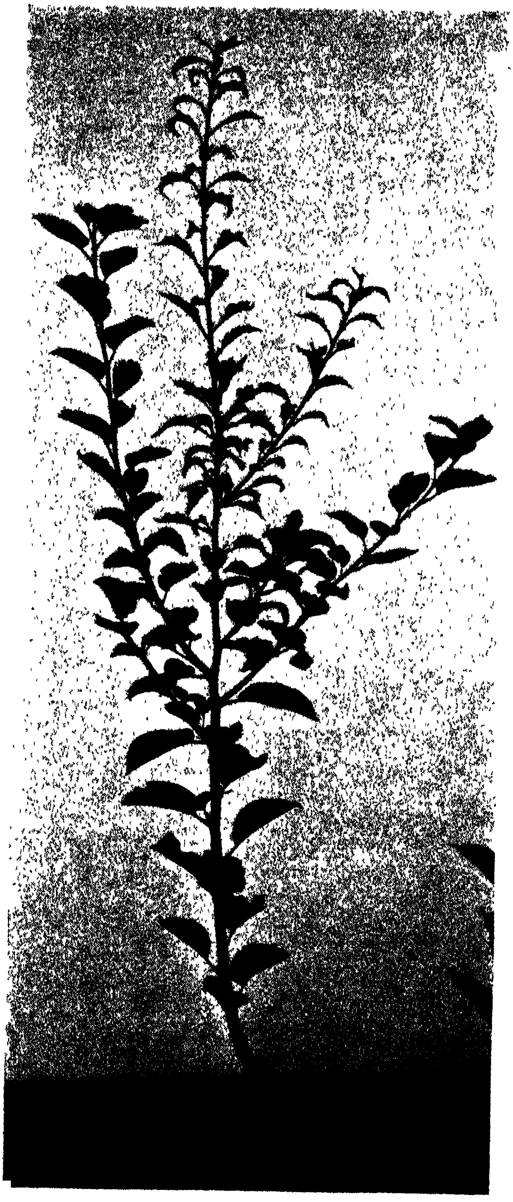

FIG. 2. One-year Baldwin tree. During the growing season, the terminal growth rather abruptly changed from the normal to the narrow-leaf type.

1.7 times thicker than normal leaves of the same variety. These thicker leaves have longer palisade cells, a thicker layer of spongy mesophyll, and a tendency toward more layers of palisade cells.

In the summer of 1940, buds from a normal shoot growing near the base of a narrow-leaf Baldwin tree were taken consecutively from the base of the shoot to its tip and budded as usual. All but one of the nine buds inserted produced normal Baldwin whips in 1941. This one exception is shown in Fig. 2 as it looked in October. During the early part of the growing season there was no evidence of abnormal growth. The exact time of its differentiation was not observed, but about 20 inches from the bud union the growth changes rather abruptly to the narrow-leaf type. This is an uncommon occurrence and resembles very closely the condition found in the original narrow-leaf trees. A similar growth procedure has become evident in a few lateral growths on 3- and 4-year-old trees. However, such cases are not so striking and clear-cut as that seen in Fig. 2 and often show intermediate leaf types which would indicate either a gradual growth change or a tendency for an existing abnormality to be altered in appearance during the growing season.

All narrow-leaf nursery trees which have been set in the orchard have produced some normal growth. In most cases, the normal character has become predominant because of the tendency for lateral buds to break into normal growth and of the comparatively much greater vigor of normal tissue. Attempts to obtain entire trees of the narrow-leaf type by a continual pruning off of the normal shoots have been unsuccessful. One 3-year-old narrow-leaf McIntosh tree has only two small normal shoots. Even on this exceptional tree, it is probable that normal foliage will prevail eventually.

Experiments are underway which it is hoped will throw light on the true nature of these narrow-leaf variations.

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The Inheritance of Blossom Type and Blossom Size in the Peach[1]

By J. S. BAILEY and A. P. FRENCH, *Massachusetts State College, Amherst, Mass.*

PEACH blossoms have long been divided into three classes or size-type according to the size and shape of their petals. These classes, large, medium, and small, were described by Connors (6) in 1919. Blake (1, 4) has more recently called the large, or broad-petaled, class "showy" flowered. Connors (5, 7) reported that large- and small-sized blossoms were homozygous for size and that medium was heterozygous. Therefore, when selfed, large and small size bred true while medium split up 1 large, 2 medium, and 1 small. As Connors (6) pointed out, the break between the large, or showy-flowered type, and the medium and small, or nonshowy type, is a very distinct one.

The work at the Massachusetts Station was started in 1923 when the first observations on blossom size were made by J. K. Shaw. As the work progressed, it became increasingly evident that the inheritance of blossom size and type could not be explained by a 1:2:1 hypothesis.

If the type of blossom, showy or nonshowy, is controlled by a single pair of genes, the F_2 should segregate 3 nonshowy to 1 showy. Table I shows that such a segregation does occur. Nonshowy (Sh) is dominant and showy (sh) is recessive.

TABLE I—INHERITANCE OF BLOSSOM TYPE

Parentage	Parental Phenotype	Blossom Type			χ^2
		Non-showy	Showy	Total	
Belle selfed	Nonshowy	386	119	505	0.555
Champion selfed	Nonshowy	464	164	628	0.416
Elberta selfed	Nonshowy	77	31	108	0.790
Gold Drop selfed	Showy	1	77	78	—
T-C18 selfed	Showy	0	87	87	—
Chili selfed	Showy	1	44	45	—
Crosby selfed	Nonshowy	88	0	88	—
Fitzgerald selfed	Nonshowy	92	0	92	—
Belle × Elberta	Nonshowy × nonshowy	119	33	152	0.877
Belle × Champion	Nonshowy × nonshowy	416	112	528	4.040*
Belle × Gold Drop	Nonshowy × showy	63	54	116	0.698
Elberta × Chili	Nonshowy × showy	48	47	95	0.010
Elberta × Vainqueur	Nonshowy × showy	29	29	58	—
Gold Drop × Elberta	Showy × nonshowy	10	13	23	0.391
Belle × T-A3	Nonshowy × nonshowy	248	76	324	1.234
Hale × Crosby	Nonshowy × nonshowy	29	17	46	3.130
Belle × Motions Cling	Nonshowy × showy	94	53	147	11.469†

*Below 5 per cent point.
†Below 1 per cent point.

It will be noted that the varieties Belle, Champion and Elberta are heterozygous for showy flowers since when selfed the offspring segregated 3 nonshowy to 1 showy with low Chi-square values. When two heterozygous varieties were crossed (T–A3 is a nonshowy-flowered

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seedling of Belle selfed), their offspring also segregated 3:1 with low Chi-square values. The value 4.040 for Belle x Champion is probably not far enough from the 5 per cent point to be significant. When a showy-flowered variety was crossed with a heterozygous nonshowy-flowered variety the expected 1:1 ratio was obtained except in the case of Belle x Motions Cling. The varieties Crosby and Fitzgerald, nonshowy-flowered types, are obviously homozygous for nonshowy flowers. Gold Drop, Chili and T–C18, a seedling of Belle selfed, are evidently homozygous showy-flowered types.

An attempt was made to separate the nonshowy class into medium and small-blossom types. In doing this, the authors tried to follow as closely as possible the size classes set up by Connors (6). After enough blossoms had been measured to fix the size types well in mind, the seedlings were classified by observation. If such a classification can be successfully made, the seedlings of heterozygotes selfed or crossed should segregate 1 large, 2 medium, 1 small. The results in Table II cast considerable doubt on the 1:2:1 hypothesis.

TABLE II—INHERITANCE OF BLOSSOM SIZE

Parentage	Parental Phenotype	Blossom Size			Total	χ^2
		Showy	Nonshowy			
		Large	Medium	Small		
Belle selfed	Nonshowy	37	129	33	199	17.753†
Champion selfed.	Nonshowy	140	267	144	551	0.582
Belle ×T-A3 . .	Nonshowy ×nonshowy	76	190	58	324	11.679†

†Below 1 per cent point.

Since the medium- and small-blossomed types grade into one another an attempt was made, starting in 1939, to separate the nonshowy group into four classes, medium, near-medium, near-small, and small. It was hoped by this means to determine with greater certainty a dividing line between the two types. Table III gives the results of this new size classification. Inspection of the tables shows that if the near-medium group were placed in the medium class, the data would not come anywhere near a 1:2:1 ratio. Therefore, the near-medium, near-

TABLE III—BLOSSOM SIZE CLASSIFICATION

Parentage	Parental Phenotype	Showy	Nonshowy					Total	χ^{2*}
		Large	Medium	Near Medium	Near Small	Small	Unclassified		
Champion selfed.	Nonshowy	67	96	21	11	28	3	226	4.749
Belle selfed (1939 data only).....	Nonshowy ×nonshowy	25	52	24	6	29	0	136	24.529†
Belle ×Champion	Nonshowy ×nonshowy	112	307	63	19	18	9	528	17.944†
Belle ×Elberta...	Nonshowy ×nonshowy	33	76	15	8	16	4	152	0.594
Belle ×T-A3 (1939 data only)	Nonshowy ×nonshowy	76	165	50	12	17	0	320	0.477

*χ^2 values calculated for a 1:2:1 ratio, using the sum of the near medium, near small, and small individuals as the small class.

†Below 1 per cent point.

small and small classes were combined and Chi-square values for a 1:2:1 ratio calculated.

The results show that such a classification of size types has not helped. While the Chi-square value for Belle × Elberta is low, and that for Belle x T–A3 has been changed from a high to a low value, that for Belle selfed has been increased to a high value, that for Champion selfed has been increased to the 5 per cent point, and that for Belle x Champion is high. This failure to consistently improve results by any reclassification of the data emphasizes again the difficulty of dividing the nonshowy class into medium- and small-flowered types. It strongly suggests that the large-medium-small classification is a purely artificial one not in accord with the genetic facts.

The authors and Blake (3) have observed size variations within the showy-blossomed class. Large blossoms with petals of the nonshowy type occasionally occur within the nonshowy class as illustrated recently by Blake (2). These size variations also suggest that the 1:2:1, large-medium-small, hypothesis over-simplified the situation and that the type and the size of blossoms are controlled by different pairs of genes.

The data presented indicate that (1) the showy-nonshowy characters are controlled by one pair of genes, Shsh; and (2) blossom size is controlled by a different pair or pairs of genes.

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Preliminary Storage Experiments with Pollen of Tung (Aleurites fordii Hemsl.)

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THE flowers of *Aleurites fordii* Hemsl., the species of tung used for commercial planting in the United States, appear so early in the season that they are frequently killed by late spring frosts. A late blossoming variety of tung, if commercially desirable in other respects, would be of great value to the industry. Although individual tung trees are in bloom for only a few days, in a seedling orchard some trees flower a month or more before others. During 1940 the flowering period at Bogalusa, Louisiana extended from late March to the middle of May while in 1941 it extended only from the middle of April to the middle of May. The desired variety might be obtained by hybridizing trees that have the best fruit and tree characteristics with the trees that consistently bloom latest. Another possibility is to make interspecies crosses between *A. fordii* and *A. montana* Wils., a species that flowers several weeks later than *A. fordii*, but is inferior in yield, oil content and resistance to cold. In either case pollen from desirable trees of *A. fordii* would need to be kept viable for a month or more.

Entirely aside from the specific objective of obtaining a desirable late-blooming variety, storage of pollen for one or more days is necessary for most hybridization work with tung. It is known that individual trees of *Aleurites fordii* may show wide fluctuations in blooming date from season to season. Sometimes a tree that blooms early one year may bloom late the next. Since trees desirable for hybridization are often chosen on the basis of characters observed at harvest time in fall, one can not predict when they will bloom. If they blossom at different times, storage of pollen is essential to effect the crosses.

The specific objects of the investigation were to determine: (a) a suitable technique for artificial germination of tung pollen; (b) the best method of handling pollen, whether it should be removed from the anther, left within the anther, or stored in the entire flower; (c) the longevity of stored pollen when gathered at different stages of maturity; and (d) the effect of different storage temperatures on the longevity of the pollen.

The effect of relative humidity on pollen stored as anthers was also studied. Germination and longevity at different humidities did not vary widely, and additional data will be required before definite conclusions as to the optimum humidity can be drawn. This phase of the investigation will be reported in a future publication.

In early attempts to germinate tung pollen, the grains ruptured on 1 per cent plain agar because of the low osmotic pressure of the medium. The addition of 1 or 2 per cent of sucrose resulted in some germination although most of the grains still ruptured. The tubes of those that germinated ruptured before making much growth. As the sugar content of the medium was increased up to 10 per cent, both percentage of germination and length of the germ tubes increased. The medium used throughout this investigation was 1 per cent agar with 10 per cent sucrose, which resulted in very satisfactory germination and pollen tube growth. The reaction of this medium is about pH 6.4.

The medium was heated and several drops placed on a clean microscopic slide. As soon as the medium had congealed, pollen was scattered over the surface, either by transferring it by means of a camel hair brush from anthers stored in vials or, when whole flowers were stored, by rubbing the anthers over the surface of the agar. The slide was then placed on edge in a covered, flat staining jar containing several drops of water. The pollen germinated best in a high relative humidity. After being kept approximately 24 hours at room temperature, ranging between 20 degrees C and 26 degrees C, the percentage of germination was determined by counting 100 grains at random under a low power microscope.

Various methods of collecting and storing pollen were tried. Pollen in large quantities was obtained by means of a trap that removed the pollen from bees as they entered their hive. This pollen was in small homogenous pellets and that from tung trees could readily be distinguished and separated from other sorts. This pollen failed to germinate, however, because of mechanical injury, age, or some unknown cause. Anthers were collected and dried in a manner similar to that described by Nebel and Ruttle (1), but they failed to dehisce after drying. The pollen adhered to the anther so closely that it was impossible to separate one from the other and it was found necessary to store the entire anther. Whole flowers were also stored in paper bags, with very satisfactory results.

Anthers were removed from the filaments of flowers in three different stages of development, as follows: (a) flowers in the bud stage not less than 1 centimeter in length and with petals almost ready to open; (b) mature flowers that had opened and were still on the tree; and (c) flowers that had fallen to the ground. The pollen was plentiful in the anthers of the flowers in the bud stage of development while the amount left in the anthers of the flowers in the two more advanced stages of development was scanty. These anthers were stored in vials at 5 degrees C.

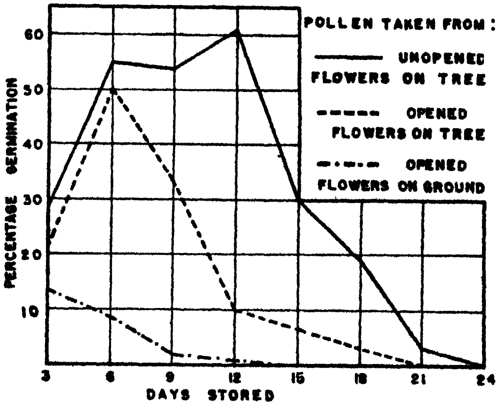

FIG. 1. Longevity of pollen and flowers of different ages.

The results are presented in Fig. 1. Each point on the graph represents counts of 100 pollen grains from each of 18 different slides. Of the 18 slides representing each age of flower at each date, 3 were prepared from pollen that had been stored at 10 per cent relative humidity, 3 at 40 per cent, 3 at 65 per cent, 3 at 90 per cent, 3 at 95 per cent and 3 at 100 per cent. These readings were combined to give the figures shown in the graph. The pollen from the flowers in the bud stage had the highest percentage of germination throughout the storage period and remained viable much longer than that from the anthers of the more mature flowers. The pollen from flowers that had fallen to the ground had a very much lower percentage of germination than that taken from flowers still on the tree.

Anthers from flowers picked at various stages of maturity were stored in vials at 5 degrees C, 30 degrees C, and at room temperature. At room temperature and at 30 degrees C, these molded very rapidly. At 5 degrees C, 38 per cent of the pollen grains were viable on the sixth day, after which the percentage that grew declined gradually until on the twenty-first day only 1 per cent germinated (percentage of total germination for all three stages of maturity shown in Fig. 1).

Whole flowers in paper bags were stored at 5 degrees C, and at room temperature. In this case no effort to control humidity was made. The data are shown in Fig. 2. Each point on this graph represents counts from three different slides. At room temperatures the pollen had completely lost its viability by the ninth day. Anthers in flowers that remained moist had molded and pollen from dried flowers did not germinate. Pollen from similar flowers held at 5 degrees C showed high viability for 24 days, at which time the supply of good flowers was exhausted. If a larger supply of flowers picked in the bud stage had been stored, it seems likely that a rather high percentage of germination would have been obtained for an even longer period.

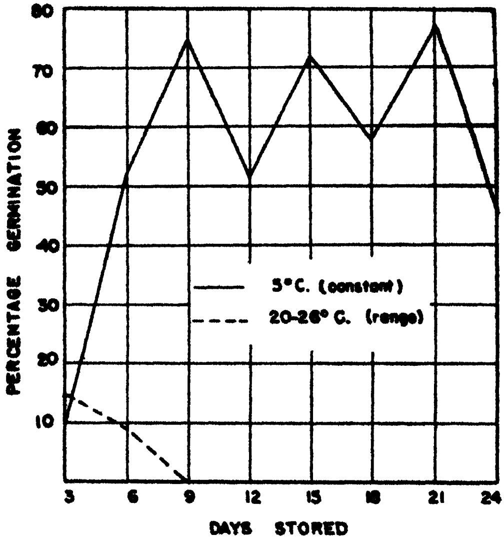

FIG. 2. Longevity of pollen stored in flowers in paper bags at different temperatures.

SUMMARY

Pollen of tung, *Aleurites fordii* Hemsl., germinates readily on 1 per cent agar with 10 per cent sucrose, when incubated 24 hours at room temperature in a practically saturated atmosphere. Pollen may be handled either by storing entire flowers or anthers. Pollen from buds collected just before anthesis gives best viability and longevity. The pollen either molds or dries out rapidly at room temperature, but is held very satisfactorily at about 5 degrees C. Storing whole flowers in paper bags at about 5 degrees C in an ordinary household refrigerator is the most practical method of keeping pollen for later use in breeding work.

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Iron Deficiency of Tung

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ABSTRACT

This material will be published as a bulletin of the Florida Agricultural Experiment Station.

TWO physiological disorders due to a deficiency of microelements have thus far been identified in tung plantings in Florida; namely, "bronzing", a zinc deficiency, and "frenching", a manganese deficiency. This new disorder, termed "iron deficiency", was first noted in one orchard in Alachua County, Florida, in 1939, and in two additional orchards in 1940. The data presented show that control can be effected by spray treatments with a 1.0 per cent solution of a C. P. grade of iron sulfate. Likewise, soil applications, though limited in extent, indicate that control can be effected by this method of treatment. In two orchards this disorder was associated with an acid soil reaction. However, in the third orchard affected trees were found on both acid and alkaline soils. In this case the alkaline reaction was produced by overliming small areas of soil in which a few of the trees are located.

The Croisic (Cordelia) Fig

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IN a recent article (3) I described briefly the Croisic (Cordelia), caprifig. The following paragraphs present a more detailed account of this unusual variety.

HISTORY

Apparently Gallesio (6) was the first to call attention to this type of fig, which he called *"Fico mula,"* the fruits of which develop hollow achenes similar to fertile seeds.

In 1882, Solms-Laubach reported (11) observations both at Croisic and at Cherbourg, France, of an edible fig which like the caprifig had a zone of male flowers inside near the eye. Three years later he expressed the opinion (12) that Croisic is simply a highly developed caprifig deprived of the blastophaga which normally inhabits caprifigs.

In July 1893, Gustav Eisen (4) noticed in the San Francisco market some large yellow figs shipped from Cordelia, California. He examined the fruit and found "every one with a fully developed zone of male flowers, fully ripe, and with an abundant, perfectly developed pollen". Eisen concluded it was possible that this fig was identical with the Croisic fig described by Solms-Laubach, but he placed it in a special class or type, the Cordelia, or *Ficus carica relicta.*

Trabut (13) described a variety of male fig tree cultivated at Angers, France, which produced figs absolutely identical with those of Croisic. Leclerc du Sablon (8), without personal study, concluded like Solms-Laubach that Croisic is a male fig tree producing edible figs in a country where the blastophaga does not exist.

NOMENCLATURE

The name Croisic comes from the town in France where Solms-Laubach first found this fig. Similarly the name Cordelia refers to the town where the figs were first found in California.

St. John, imported by the United States Department of Agriculture in the Chiswick collection from England under number 18858, has proved to be identical with Cordelia. Lawrence found (7) in Arizona that Bellona and Drap d'Or figs had staminate flowers in the apical portion of the receptacle and therefore placed them in the Cordelia class. From descriptions found elsewhere, it is evident Lawrence did not have these two varieties true to name. Eisen describes (5) Pingo de Mel as belonging to the Cordelia class. O. T., in Gardener's Chronicle, October 7, 1905, page 258, says that St. John (synonym, Pingo de Mel) is undoubtedly the best of all varieties for early forcing. Watson (14) also recommends St. John (Pingo de Mel) for pot culture. It was introduced into England about 1890 by J. Veitch and Sons.

A fig under the name Pingo de Mel was grown in the Coachella Valley, California, in 1916 and also at the L. J. Nickel estate, Menlo Park. In both places the figs were identical with Cordelia.

Occurrence on the Pacific Coast

The Croisic was probably introduced into California some time after the middle of the nineteenth century. Eisen found fruit in the San Francisco market in 1893. In 1914 George Roeding reported (10) Cordelia trees widely distributed in the San Joaquin Valley. In May the trees heavily laden with profichi look very much like good caprifig trees. Inexperienced growers have sometimes been persuaded to buy the crop for caprification purposes. As far back as 1922, however, I (2) called attention to the worthlessness of these caprifigs on account of the almost total absence of blastophagas to carry pollen if any should be present.

The Cordelia is especially common in the vicinity of San Francisco Bay. Rixford (9) described three trees 20 years old in 1920, growing near the Bay shore, one of the windiest and bleakest spots in San Francisco; however, the first crop ripened perfectly and sometimes the second crop matured. One grower in Oakland reported his trees were grown from cuttings brought from Genoa, Italy. Figs from dooryard trees in Berkeley, Oakland and Alameda are commonly offered for sale in fresh-fruit markets.

This same variety is being grown commercially in Oregon. B. R. Amend, Portland, obtained it from the Felix Gillet Nursery, Nevada City, California, and grows it under the name Gillette. I found it in August, 1932, on a fruit stand near Dillard, Oregon, and trees are said to be bearing at Roseburg under the name Golden Dewdrop.

Fruiting Behavior

Cordelia is essentially a caprifig and it behaves like one. In April the profichi appear profusely from fruit buds which have been dormant during the winter. In the hot interior valleys they reach full size in late May or June, the figs being fairly large, greenish-yellow, pulpy, and edible, but hardly delectable to a fig connoisseur. In cool, coastal climates they may not mature until July or even August, the ripe fruit being light green and pulpy and decidedly insipid compared to such other figs as Kadota and Mission. It is the profusion of the first-crop figs which has attracted the attention of English gardeners to this variety for early forcing.

Like most caprifigs, in the interior valleys Cordelia produces a very scanty mammoni or summer crop, the individual figs being medium in size, greenish-yellow, and soft in texture. Near San Francisco Bay, on the other hand, Cordelia produces a good mammoni or second crop in favorable seasons, the figs which mature in October and November being of medium size and of fair quality.

Fruit Descriptions

Cordelia profichi are medium or above medium in size, about 1¾ inches in diameter, pyriform, with distinct neck; ribs generally prominent, elevated, often making the immature fruit corrugated, much less prominent in coastal districts; eye fairly large with prominent yellowish-green scales; color greenish-yellow; meat and pulp white; flavor insipid; quality fair to poor.

Second-crop or mammoni figs in coastal climates are similar to the above profichi, although smaller in size and the surface somewhat glossy.

FLOWERS

The syconium of Cordelia bears on its inner wall short-styled pistillate flowers, and near the ostiolum a mass of staminate flowers. It was the presence of the staminate flowers in the mature fruit which attracted the attention of various botanists to this variety. Solms-Laubach stated (11) that the mass of male flowers ripened less perfectly than the rest of the fig, always remaining somewhat hard and dry, so that it was generally removed before the fruit could be eaten. Eisen, as stated above, found that the figs have an "abundant, perfectly developed pollen". At Fresno in 1927 and at Riverside in 1933 and 1936 the anthers were rusty and not shedding dry pollen as do those of most caprifigs. Some anthers, however, contain pollen which appears to be normal. Eisen (5) specifically mentions gall flowers, but he does not place this variety in the caprifig class. Roeding says (10) that "to all appearances the tree is a caprifig, but all efforts to induce the blastophaga to in any way change the character of this fig have been without avail".

My observations during the past few years show that blastophagas oviposit freely in the short-styled or gall flowers of Cordelia, that the larvae develop inside, and that later the adults emerge, but not in numbers comparable to those issuing from such caprifigs as Stanford or Roeding 3. Blastophagas which do issue from flowers of mature Cordelia figs often become entangled in the soft, juicy pulp characteristic of this variety. Cordelia figs with some of the gall flowers inhabited by blastophagas are indistinguishable from other Cordelia figs uninhabited, a corroboration of the statement by Roeding (10) that the blastophaga does not change the character of this fig.

Cordelia flowers fixed, prepared by the paraffine method, and sectioned, show stylar canals injured by the wasp's ovipositor, eggs in place next to the nucellus, and larvae in various stages of maturity.

PARTHENOCARPY

Parthenocarpy, both vegetative and stimulative, is exhibited by some caprifigs. Numerous seedling caprifigs, out of a total population of 4,034 fruiting in our Station fig plots, are completely parthenocarpic, the fruits reaching pomological maturity, with pulpy edible fruit, yet with an abundance of mature pollen. Apparently Croisic (Cordelia) is, like these seedlings, simply a caprifig which shows complete vegetative parthenocarpy in the profichi crop and sometimes also in the mammoni crop. This corroborates the conclusion of Eisen (5) that Cordelia is a direct descendant from the male caprifig. "It retains its male flowers, they having not yet been eliminated, while the pomological maturity is simply an improved botanical maturity of the caprifig, as it is well known that several varieties of caprifigs are edible, though inferior in quality."

SUMMARY

The Croisic fig, named by Solms-Laubach in France in 1882, was found in California in 1893 by Eisen and given the local name, Cordelia. The fruits are edible but like caprifigs have short-styled pistillate flowers and stamens. St. John, recommended for forcing in England, is apparently the same variety. Individual trees of Cordelia are fairly common in the interior valleys of California, producing a profichi crop of no commercial value. In cool coastal climates it produces not only a profichi crop but in favorable seasons a mammoni crop as well, the figs being relished by home owners and sometimes appearing on the local markets. It is being grown to a small extent commercially near Portland, Oregon.

Croisic (Cordelia) is essentially a caprifig and it behaves like one, producing ordinarily a heavy profichi crop, a light mammoni crop, and very few or no mamme figs. Blastophagas oviposit in the short-styled pistillate flowers and all stages of this insect can be found in the syconia at various times. This variety is therefore a caprifig in which vegetative parthenocarpy is exhibited in one crop and sometimes in two crops in the same season.

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Leaf Segregation in Citrus-Poncirus Hybrids

By S. H. Yarnell, *Texas Agricultural Experiment Station, A. and M. College of Texas, College Station, Texas*

CROSSES between Citrus and Poncirus were initiated by the United States Department of Agriculture in Florida in 1897 (4). Because of competition with other embryos resulting from nucellar budding and perhaps other causes, the sexual embryo seldom reaches maturity in most of these hybrids. This leads to the development of many seedlings of maternal type, which seriously interferes with normal segregation and the recombination of characters so necessary to plant breeding. Swingle (1) found no noticeable variation in a lot of over 1,500 seedlings of the Rusk citrange — a hybrid between *Poncirus trifoliata* and *Citrus sinensis* (the trifoliate and sweet orange). Webber (3) states that he found segregation only in the Sanford in progenies of several hundred plants each of six varieties of citrange. According to Traub and Robinson (2) segregating seedlings have been distributed for trial without finding anything of horticultural value, but it appears that little has been done with such segregating material in further breeding.

The material was grown from seeds obtained from open-pollinated fruits produced either by budded trees or by maternal seedlings. These were obtained in Texas from R. A. Hall, Substation No. 1, Beeville; H. M. Reed, Substation No. 3, Angleton; J. F. Wood, Substation No. 15, Weslaco; and E. Mortensen, Substation No. 19, Winter Haven. Seeds of the citrumelos (trifoliate orange-grapefruit crosses) and most of the citranges were also provided by Dr. H. P. Traub while at the United States Department of Agriculture Fruit and Vegetable Crops and Diseases Laboratory at Orlando, Florida.

The results presented here, while similar to those reported earlier, differ in certain respects. Instead of the invariable production of maternals by most varieties of citranges, we have found only one lot ("un-

TABLE I—SEGREGATION OF LEAF TYPES IN OPEN-POLLINATED CITRANGE SEEDLINGS*

Variety	Maternal	Unifoliate	Semi-Unifoliate	Deciduous	Small or Weak	Other
Carrizo	70	0	0	0	0	0
Cunningham	674	1	1	0	0	4
Eustis	8	0	0	0	0	0
Morton	155	0	0	0	0	1
Norton	115	0	0	0	0	1
Rusk	1326	0	1	13	0	2
Rustic	18	0	0	0	0	0
Savage	52	0	0	0	0	0
Willits	3	0	0	0	0	0
1416	54	0	0	0	0	0
Unlabeled	985	0	0	0	0	0
Total	3460	1	2	13	0	8
Saunders	99	0	1	0	0	5
Etonia	1	1	0	0	0	1
Phelps	0	0	0	0	0	2
1425	1	0	10	0	38	10
Total	2	1	10	0	38	13

*The figures in each column represent the number of plants.

labeled") with as many as 100 seedlings that has no segregates. This tree, received at Texas Substation No. 3 a number of years ago may be a Rusk maternal. The numbers of segregates from the different varieties are grouped according to type in Table I. The leaves of the maternals are trifoliate, like those of the seed parent (Fig. 1, 11a), and

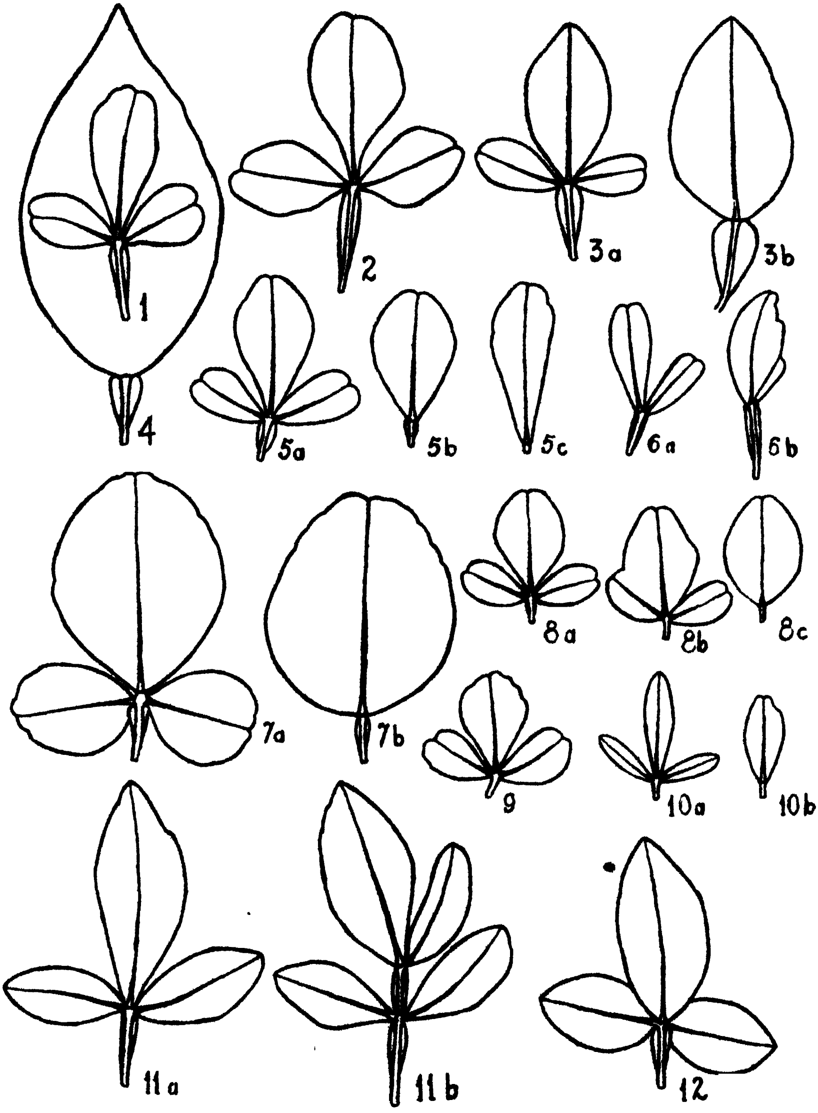

FIG. 1. Variation in leaves of citrange seedlings: 1, trifoliate orange; 2, deciduous segregate; 3a and 3b, unifoliate type; 4, Valencia orange seedling; 5–8, semi-unifoliate segregates; 9 and 10, small or weak plants (5, 6, and 8 are also smaller than normal); 11 and 12, miscellaneous segregates.

while leaves of most other types can be found on such plants, their numbers are relatively small. In the unifoliate segregates simple, normal leaves nearly exclude all other types and it is difficult to find trifoliate leaves (Fig. 1, 3a). In the semi-unifoliate plants the proportion of simple leaves is much higher than in the maternals, ranging

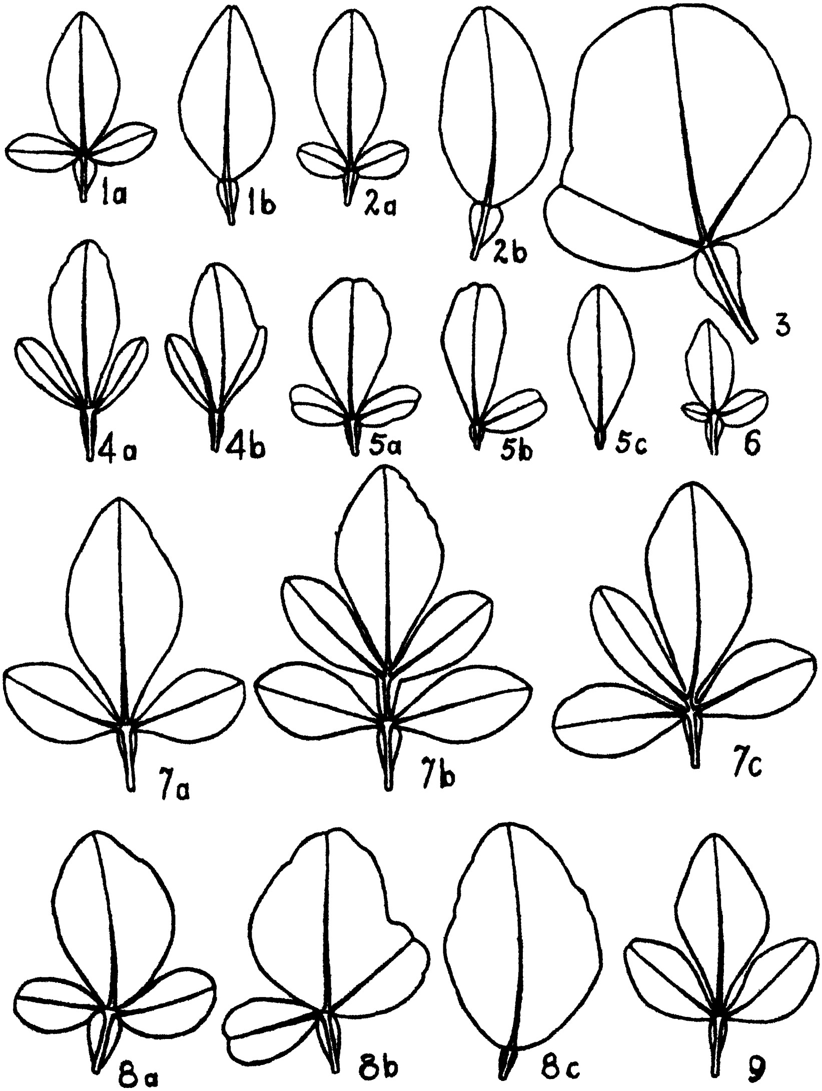

FIG. 2. Variation in leaves of citrumelo seedlings: 1a and 1b, semi-unifoliate; 2a and 2b, unifoliate; 3, abnormal leaf of a maternal mature tree; 4a and 4b, trifoliate and abnormal leaves of unifoliate type; 5a, b, and c, segregate of miscellaneous group; 6, semi-unifoliate (note unbalanced lateral leaflets) ; 7, 8 and 9, three segregates of the miscellaneous group.

TABLE II—TYPES OF SEGREGATES

Group	Unifoliate	Semi-Unifoliate	Deciduous	Small Weak	Other
		Citrange			
Very low	1	2	13	0	8
Low	0	1	0	0	5
High	1	10	0	38	13
		Citrumelo			
Very low	0	2	1	0	3
Low	2	7	0	2	12
High	9	7	0	3	17

roughly from 25 to 50 per cent. Abnormal leaves may be present as in the maternals (Fig. 1, 5 to 8). The deciduous seedlings are very close to the trifoliate orange both in appearance (Fig. 1, 1 and 2) and in behavior. Not only the leaves but the habit of growth are that of *Poncirus trifoliata*. Since these seedlings have resulted from open-pollinated flowers it is possible that they represent a back-cross instead of a self-pollination. In either case these 13 Rusk seedlings probably have resulted from the development of the sexual embryos. The small or weak plants vary more in leaf shape between plants than do the other types (Fig. 1, 9 and 10). This seems to be due to the segregation and recombination of numerous genetic factors. All 38 seedlings of this type appeared in a single family of citrange No. 1425, the seed of which was obtained from Dr. Traub. Finally, certain seedlings differing sufficiently from the maternals to be considered as true segregates yet failing to conform to any of the other types have been placed in a miscellaneous group (Fig. 1, 11 and 12). It is possible that some of these are of adventitious origin and should be classed with the maternals, and this may later become evident.

The citrumelo segregates fall into the same five types (Fig. 2), although the proportions are somewhat different (Table II). There are more strictly unifoliate plants and only one of the deciduous type. Also there are fewer small or weak plants and more have been placed in the miscellaneous group.

In both citrange and citrumelo the varieties can be placed in three classes based upon the proportion of segregating plants in their progenies, as follows: (a) very low — under 1 per cent; (b) low — from 5 to 10 per cent; and (c) high — from 70 to near 100 per cent (Table III). A difference is noted between citrange and citrumelo in the num-

TABLE III—PROPORTION OF SEEDLINGS SEGREGATING

Group	No. Varieties	No. Maternals	No. Segregating	Per Cent Segregation
	Citrange			
Very low	11	3460	24	0.69
Low	1	99	6	5.71
High	3	2	62	96.87
	Citrumelo			
Very low	5	677	6	0.77
Low	6	197	23	10.05
High	6	14	36	72.00

ber of varieties falling in each class. Most of the varieties of citrange are in the very low class, while less than one-third of the citrumelos segregate less than 1 per cent. It will be noted that a higher proportion of the citrange varieties are showing a large amount of segregation than has been previously reported, and a new class consisting of a single variety, (the Saunders) with over 5 per cent of its seedlings resulting from sexual embryos has been observed.

From the standpoint of segregation the citrumelos seem to hold somewhat greater opportunity for plant breeding than do the citranges. A consideration of the observable leaf segregation in these populations indicates the proportion and type of sexual seedling development in the different varieties and the corresponding possibility of new gene combinations affecting other characters.

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Growth and Yield of Steele Red Apple Trees as Influenced by the Use of Various Double-Worked Interstocks[1]

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THE introduction of a stem piece, or double-worked interstock, between a rootstock and a scion may modify their growth according to the interstock that is used. Studies made by Maney (4) and McClintock (5) on the use of top-worked interstocks have shown that different interstocks influence the yield as well as the growth of the scion worked upon them. Reports on the influence of double-worked interstocks on the growth and yield of the scion variety have shown somewhat similar results (1, 2).

A distinction between double-worked and top-worked interstocks should be made at this point in order to clarify the discussion that is to follow on this subject. A double-worked interstock is here considered to be one which forms only the trunk of the tree. It is introduced into a tree by first budding or grafting the interstock variety on to a seedling stock and then, after the interstock has grown for a year in the nursery, grafting the scion variety on to the resulting interstock. A top-worked interstock, on the other hand, is one in which the interstock has been grown in the nursery or orchard for several years, after which the scion variety is worked on to the scaffold branches of the interstock. Thus in top-working the interstock forms the framework of the tree, whereas in double-working, the interstock forms only the trunk of the tree.

The experiment reported herein is part of a more extensive study to determine the effect of interstocks on yield, season of ripening of wood and fruit, color and size of fruit and size and longevity of tree. The specific purpose of the experiment discussed in this paper was to find out whether the choice of interstock used in double-working makes any practical difference in the growth and yield of Steele Red trees.

Material and Method

The variety Steele Red was chosen as a suitable scion because of its reported lack of vigor and the difficulty that nurserymen have had in producing a high percentage of first class trees. Such a variety might be expected to respond to any invigorating effect that would be derived from the use of a vigorous interstock. In addition, Steele Red (Red Canada, Old Nonsuch) had the advantage of being a very high quality, late-keeping dessert apple grown commercially in Michigan and to a less extent in several other states. Any findings from this study would therefore lend themselves to immediate practical application.

The varieties chosen as interstocks were selected on account of their reputed vigor or hardiness and included Fameuse, Haas, Jonathan, Northern Spy, Red Astrachan, Tolman, Virginia Crab and Yellow

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[1] This study was planned and started by F. C. Bradford to whom the author wishes to express his thanks for suggestions in preparing the manuscript.

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Bellflower. Steele Red interstocks and seedling stocks were used as the basis for comparison.

As originally set out, the experiment consisted of 713 trees divided into three plantings. The first and second plantings were made in the spring and fall of 1932 respectively, while the third planting was made in the spring of 1934. All three plantings adjoined one another. The trees were thus 10, 9, and 8 years old at the conclusion of the 1941 growing season. This method of repeating the planting in successive years served as an excellent check on the results and permitted the addition or elimination of material as seemed fit. Thus, in the third planting, trees double-worked with Steele Red interstocks were added to the experiment as being a more suitable basis for comparison than trees worked directly on seedling stocks, which, as explained in greater detail later in this paper, were in reality only single-worked trees. During the spring of 1939, half of the trees in the first two plantings were removed so as to give the remaining trees more space to develop. In the spring of 1941, alternate trees were removed from the third planting. The trees removed from the first two plantings were used for growth analyses (3).

The method of producing the trees studied in this experiment followed with one exception the conventional procedure as described in the introductory discussion of double-working. This exception consisted in budding the scion on to the interstock rather than using the conventional tongue graft. This method was adopted in the belief that the Steele Red growth would be more uniform from buds than it would be from tongue grafts. Also, scions grown from buds would make a smoother stretch of Steele Red trunk for subsequent circumference measurements than could be secured from grafts, which generally develop three or four buds from the original scion.

Yield and growth records were taken every year. It has been shown (3) that trunk circumference measurements serve as a satisfactory method for comparing tree size. Such a method was therefore used in this study. Weight and number of fruits for each tree were recorded at harvest. Only weight records have been included in the following table as number of fruits were highly correlated with weight of fruits and showed little effect of interstock influence at the time that these records were taken.

RESULTS

Trunk circumference measurements, as shown in Table I, indicate that certain interstocks definitely increase or decrease the size of the tree. In the first and third plantings, trees having Northern Spy interstocks were significantly larger than trees on seedling stocks, and in the third planting, significantly larger than those with Steele Red interstocks. The use of Fameuse as an interstock increased the size of the trees in only one out of the three plantings in which it was included. Red Astrachan interstocks, which were used only in the third planting, significantly increased tree size over that of trees grown on seedling stocks and also those on Steele Red interstocks. In addition, Jonathan and Haas interstocks produced trees which were larger than those

TABLE I—TRUNK CIRCUMFERENCE OF STEELE RED TREES ON VARIOUS INTERSTOCKS

Interstock	No. of Trees	Trunk Circumference (Cm)	Coefficient of Variation	Significant Difference From		
				Seedling	Virginia Crab	Steele Red
		First Planting				
Northern Spy	10	39.82 ±1.276	10.13	+	+	
Tolman	6	37.31 ±3.701	24.29			
Seedling	30	36.05 ±1.019	15.48			
Fameuse	6	35.36 ±3.151	21.82			
Virginia Crab	9	33.86 ±0.907	8.04			
		Second Planting				
Seedling	24	36.66 ±1.319	17.62			
Fameuse	5	35.96 ±2.160	13.43			
Northern Spy	16	35.39 ±1.404	15.87			
Tolman	12	34.14 ±1.828	18.55			
		Third Planting				
Fameuse	7	33.70 ±1.363	10.81	+		+
Northern Spy	7	32.93 ±1.022	8.21	+		+
Red Astrachan rg.*	34	32.80 ±0.633	11.25	+		+
Jonathan rg.	14	29.73 ±1.395	17.56			+
Seedling	8	29.25 ±0.831	8.03			+
Haas b	7	29.20 ±0.924	7.75			+
Haas rg.	31	29.06 ±0.462	8.85			+
Tolman rg.	10	28.47 ±1.368	15.19			
Yellow Bellflower	11	27.34 ±1.542	18.70			
Virginia Crab b32	5	26.80 ±0.919	7.66			
Virginia Crab rg.	25	25.98 ±0.584	11.24	–		
Virginia Crab b33†	7	25.74 ±0.938	9.64	–		
Steele Red	11	24.82 ±1.331	17.79	–		

*Trees produced by root grafting the interstock on to the seedling stock, designated by the abbreviation "rg".

†Bud set in 1933 and trees planted in 1934 with dormant bud.

grown on Steele Red interstocks, though not significantly larger than those worked directly on seedling stocks. On the other hand, Virginia Crab interstocks consistently reduced the trunk circumference when compared to trees grown on seedling stocks, significantly so in the third planting. The performance of Virginia Crab as an interstock is of special interest in that during the early life of the trees in this study, those having this variety as an interstock were the largest in their respective plantings, but gradually their rate of growth, as related to the other trees, slowed down until they were the smallest trees in the group.

It will be noted that in the third planting, trees on seedling stocks were significantly larger than those on Steele Red interstocks. This might at first seem unreasonable, as both sets of trees had Steele Red trunks. Those designated as being on Steele Red interstocks, however, were double-worked and were hence cut back twice, whereas those trees on seedling stocks were only cut back once. This difference may therefore be considered as just a simple effect of a more vigorous pruning treatment. Under the conditions of this experiment it was possible to increase the size of Steele Red trees by the use of Northern Spy interstocks. The data also suggest that Fameuse, Haas, Jonathan and Red Astrachan may invigorate the scion variety budded or grafted on them. Confirmatory experiments have already been started, using these varieties in further interstock studies.

Uniformity of tree size as measured by coefficient of variation of trunk circumference varied from 7.66 per cent to 24.29 per cent according to the interstock used. Trees on seedling stocks were as uniform as most of the double-worked trees. Double-working, therefore, on the basis of these results, cannot be considered as a means of producing more uniform trees, in spite of theoretical considerations to the contrary.

The accumulated yields for these 8- to 10-year-old trees are shown in Table II. By accumulating the yields for the three years that the trees have been in production, yearly fluctuations were reduced so that such yields form a truer picture of tree performance which may in turn be more closely correlated with growth measurements. Trees in the first planting having Northern Spy interstocks and those in the first and third planting having Virginia Crab interstocks were the only ones which produced yields that were significantly greater than those produced by trees on seedling stocks. When the trees on Steele Red interstocks are used as the basis for comparison, as in the third planting, then Haas, Northern Spy, Jonathan, Tolman and Virginia Crab interstocks have each increased the yield of fruit. On the other hand, in this same planting, trees on Red Astrachan, Steele Red and Yellow Bellflower interstocks all produced significantly less fruit over the three year period than did the trees on seedling stocks. These data on accumulated yield suggest that Virginia Crab may become a promis-

TABLE II—ACCUMULATED YIELD OF STEELE RED TREES ON VARIOUS INTERSTOCKS

Interstock	No. of Trees	Accumulated Yield (Lbs)	Significant Difference From	
			Seedling	Steele Red
First Planting				
Virginia Crab	9	203.23 ±20.59	+	
Northern Spy	10	159.64 ±24.93	+	
Tolman	6	146.22 ±58.81		
Fameuse	6	84.85 ±38.57		
Seedling	30	78.56 ±12.28		
Second Planting				
Tolman	12	102.52 ±19.60		
Northern Spy	16	101.06 ±19.06		
Seedling	24	90.02 ±12.95		
Third Planting				
Virginia Crab rg.*	25	74.14 ± 8.77	+	+
Haas b.	7	40.83 ± 7.95		
Haas rg.	31	34.24 ± 4.00		+
Northern Spy	7	34.17 ± 5.20		+
Virginia Crab b33†	7	33.46 ± 9.82		+
Jonathan rg.	14	28.64 ± 5.71		+
Tolman rg.	10	28.46 ± 6.06		+
Seedling	8	26.98 ± 3.16		+
Fameuse	7	22.71 ± 7.92		
Virginia Crab b32	5	20.20 ± 9.03		
Red Astrachan rg.	34	17.25 ± 2.31	−	
Steele Red	11	11.54 ± 2.13	−	
Yellow Bellflower	11	4.21 ± 1.24	−	

*Trees produced by root grafting the interstock on to the seedling stock, designated by the abbreviation "rg".

†Bud set in 1933 and trees planted in 1934 with dormant bud.

ing interstock for the Steele Red variety when earliness of bearing and large yields are to be desired. It is worth noting that in 1941, the "off" year for this orchard, trees with Virginia Crab interstocks were practically the only ones that bore much fruit. The 1941 crop, however, was not the only reason for the high yielding effect of this interstock, for in the previous season, those trees having Virginia Crab as an interstock produced the largest yields in the experiment.

Discussion and Conclusion

As has been pointed out on different occasions, each variety functions in its own peculiar way, so that an interstock variety which produces a large tree may not necessarily produce a high yielding tree, and vice versa. Thus in the case of the Steele Red trees studied in this experiment, the use of Northern Spy as an interstock produced trees which were among the largest as well as the highest yielding. On the other hand, while Red Astrachan and Fameuse interstocks produced large trees, they decreased fruit yield, significantly so in the case of Red Astrachan. Again, while Yellow Bellflower interstocks have had little influence on tree size, they have significantly reduced the yield of fruit. Finally, Virginia Crab interstocks produced the smallest trees which had by far the largest yield.

The results of this study have therefore shown that the practice of double-working influenced the size of the tree and yield of fruit of the scion variety depending on the variety used as interstock. The small size of the tree together with the large yield obtained by the use of Virginia Crab interstock is probably the most useful information obtained from this study.

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Trunk Diameters of Young Apple Trees on Clonal Stocks[1]

By J. K. SHAW, *Massachusetts State College, Amherst, Mass.*

WHEN a variety of apples is budded on itself and the wound has healed there is no external evidence of the operation. However, when any variety is budded on clonal stocks, external evidence of the operation often continues after the wound has healed and perhaps as long as the tree lives. The point of union is usually shown externally by a difference in the appearance of the bark of the stock and scion and often by a more or less pronounced swelling at the point of union. Sometimes there is a difference of trunk diameter above and below the union. There seems to be uniformity in all unions of a given stock and variety. On the other hand, when a variety is budded on seedling stocks, while there is usually a clear indication of the point of union, there seems to be much variation between the different seedling-scion combinations.

Just what happens when there is a distinct swelling and why it happens has not been made clear. There is a more or less pronounced disturbance of the differentiation of the elements of the secondary tissues. It does not usually interfere with the growth and performance of the tree. Many old top-grafted trees grow and produce well when there is a pronounced swelling and disarrangement of the tissues at the place of union.

Diameters above, at, and below the union of 900 trees, budded mostly on Malling clonal stocks while in their third year of growth in the orchard, were taken in June, 1941. Some of these measurements are shown in Table I. The diameters of the swell and of the stock were always larger than that of the trunk above the union and are expressed as per cent of trunk diameter.

Malling stocks I to IX inclusive are known to exert more or less distinct dwarfing effect on all varieties, while the other stocks listed are known to dwarf trees little or not at all. The trunk diameter at this age gives little indication of dwarfing effects by the stock. Many additional data in support of this conclusion could be given. Perhaps dwarfing is due largely to early bearing, which diverts the products of photosynthesis from growth of the tree to growth of fruits. This problem will be carefully studied as the trees develop.

The swell, when dwarfing stocks are used, is larger than with the vigorous stocks. With Malling I it is smaller and with Malling IX, larger than with the other four dwarfing Malling stocks. Malling XII seems to produce less swell than do XIII, XV, and XVI. The figures show less differences than was expected on the basis of previous observation.

It was believed from general observation that R. I. Greening, Gravenstein, and Oldenburg would show a larger swell than other varieties. The figures in the table give little support to this idea. Golden Delicious and Red Spy show as much or more swell. Baldwin,

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[1] Contribution No. 426 from the Massachusetts Agricultural Experiment Station.

TABLE I—TRUNK DIAMETERS OF TREES ON CLONAL STOCKS

Stock	Number Trees	Average Trunk Diameter (Mm)	Per Cent of Trunk Diameter	
			Stock	Swell
	Baldwin			
II	9	29.6	109	137
III	8	27.1	122	144
IV	9	27.1	118	138
XII	9	28.7	104	120
XIII	9	27.8	108	124
XV	9	26.7	122	135
323	11	31.5	113	130
	Golden Delicious			
I	9	21.4	113	131
III	8	22.0	125	158
IV	9	28.1	119	142
V	9	22.9	128	144
V	13	22.8	119	141
IX	8	21.8	163	218
IX	12	21.6	157	184
XII	9	29.2	117	117
XVI	8	25.6	119	128
C	10	26.3	115	128
	Kendall			
I	9	25.6	122	129
II	9	28.7	118	132
III	8	20.1	119	147
IV	9	25.7	119	139
V	9	27.0	125	140
XIII	11	25.8	116	125
XV	10	24.5	121	129
	McIntosh			
I	9	21.1	135	139
II	9	24.1	114	128
III	12	18.8	132	142
III	8	23.5	117	127
IV	9	23.6	120	142
IV	7	22.4	111	137
V	9	23.2	120	130
V	6	24.8	138	181
IX	8	25.0	121	131
XII	9	24.6	110	121
XIII	9	25.9	114	128
XV	9	23.6	122	137
XVI	8	26.1	115	132
323	10	24.7	117	136
C	11	23.7	118	137
	Oldenburg			
I	9	21.9	112	131
V	9	24.0	125	149
IX	8	23.0	123	134
XVI	8	25.9	124	141
	Red Gravenstein			
I	9	31.1	112	129
III	8	27.8	130	144
IV	9	29.4	119	159
V	9	39.2	118	164
XIII	10	30.3	113	122
XVI	5	39.4	107	125
S	5	25.4	102	128
	Red Spy			
I	8	17.4	110	126
II	9	27.2	115	140
III	8	21.0	116	153
IV	9	25.6	113	133
V	8	26.0	119	138
V	13	22.8	124	151
IX	8	18.0	158	202
IX	12	18.7	163	199
XVI	8	27.0	107	126

TABLE I—*Concluded*

Stock	Number Trees	Average Trunk Diameter (Mm)	Per Cent of Trunk Diameter	
			Stock	Swell
		R. I. Greening		
I	9	25.2	102	133
V	10	30.2	111	144
IX	8	28.0	109	141
XVI	8	30.8	110	122
		Starking		
II	9	25.6	107	123
III	8	25.4	124	144
IV	9	22.0	124	151
IX	8	19.8	167	200
X	5	21.6	128	154
XII	9	26.0	109	115
XII	5	25.4	109	122
XIII	9	19.9	112	141
XV	9	23.4	117	136
A	5	20.8	113	125
C	10	24.2	113	126
		Wagener		
I	9	24.7	106	116
V	9	25.7	107	121
IX	8	24.8	113	133
XVI	8	24.5	110	134

McIntosh, and Wagener seem to show less than other varieties. There seems to be no correlation between vigor of the variety and enlargement at the union.

In all cases the diameter below the union is larger than that above. With most trees there was a space between the swell at the union and that caused by root development, but in some cases it was impossible to get a satisfactory measurement. Therefore, the measurements may be subject to a greater error than those above and even of the swell. Malling III and V unbudded shoots seem more slender than those of the other stocks, yet with the budded trees these measurements are larger than with other dwarfing stocks. There is some suggestion that the dwarfing stocks show a greater diameter than standard stocks and that Malling IX has the largest diameter. Stock diameters are relatively large when budded with Golden Delicious and with Red Spy. There is a suggestion that the diameter of the stock below the union is correlated with that of the swell.

There may be characteristic effects of each combination of stock and scion but numbers are too few and experimental error too great to make such figures significant.

Experiments with present clonal stocks and varieties must yield some general principles if they are to have permanent value. By the time we learn of the behavior of present stocks and scions, new stocks and new varieties will be with us and we will have to do the work all over again unless we can learn something that will enable us to forecast the behavior of new combinations from the characters and behavior of new stocks and varieties, or from budded trees in the early years of their life. It seems doubtful if the behavior at the union of these trees through the first three years in the orchard gives us very much on which to forecast the performance and value in the orchard but the problem will be kept in view as the orchard grows.

Orchard Identification of Stone Fruit Rootstocks

By LEONARD H. DAY, *University of California, Davis, Calif.*

INVESTIGATIONS in orchards frequently require a knowledge of the rootstock. In California sweet cherry trees are grown on one of three rootstock species — Mazzard, Mahaleb or Morello. The other stone fruits may be upon roots of peach, apricot, almond or Myrobalan. Some prune and plum varieties are grown on all four of the latter. It is not as easy to identify the rootstocks of old, sickly, or dead trees as it is those of nursery trees or of young trees in the orchard. Further complications arise when the grafts are below ground and large scion roots have grown out above the union. Sometimes it is necessary to identify roots of trees that have been dug up and are completely dried out.

A number of papers on identification of rootstocks have been published, particularly by Heppner (1), Tukey (4), Upshall (5), and Rawlins and Jarvis (2). The author has used the suggestions contained in these papers and has observed certain other characteristics which are especially helpful in the orchard in making rapid determinations at the graft union without the removal of more than a few inches of soil below the union; tests which may usually be made in a fraction of a minute.

APRICOT, PLUM, PEACH AND ALMOND ROOTS

The chief distinguishing feature of apricot roots is the beet-red or blood-red[1] color of the surface and a violet to red-violet[2] color and metallic lustre of the underside of the thin superficial cork layers. The latter colors are readily uncovered by scraping the surface with a knife. Even in roots that have been dead for some time this color may be detected beneath the cork tissues surrounding the lenticels. The above characteristics are especially useful in distinguishing apricot roots from those of peach or almond which have turned red, either inside or out, from age or other causes. With mature trees a very thick layer of cork may be present over the surface of the root-crown and in apricot there is a dark red[3] color and flecks of violet on the under surface of or between layers of this material.

The Myrobalan plum root is much darker in surface color than that of peach and almond; varying through shades of light to dark brown,[4] or rarely, reddish brown. When moist, the darker tones appear almost black. There are with this root numerous single lenticels scattered irregularly over the surface between the rows of lenticels. The cellular tissue inside of these structures is much whiter than is the case with other rootstock species of this group. Moreover, the tops of the lenticels break off quite readily, such that when the root is scraped very lightly they become conspicuous as a speckling of white dots over the dark background of the surface (Fig. 1). This characteristic is so

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[1] Ridgway's ox-blood red.

[2] Ridgway's Hellebore red, deep Hellebore red and Mars violet.

[3] Ridgway's Pompeian red.

[4] Ridgway's Rood's brown, chocolate, burnt umber.

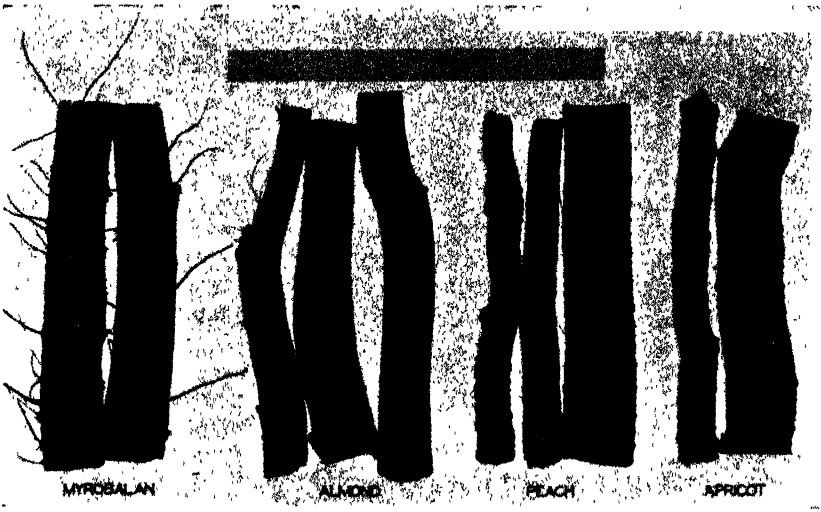

FIG. 1. Typical specimens of roots from trees 15 years of age, showing some of the characteristics described in the text. Note with the Myrobalan the numerous single lenticels between the transverse rows and the white tissues (left specimen) exposed by scraping off the tops of these structures, also the numerous "wiry" laterals.

conspicuous that it is only necessary to remove a few inches of soil at the root crown to detect it. Old almond roots may have a considerable number of single lenticels but seldom are they as numerous as with Myrobalan, and they lack the white color of the inner tissues. Another feature of Myrobalan roots is the presence of numerous long, wire-like, laterals (Fig. 1). The aforesaid characteristics of the Myrobalan seem also to be common to the other plum stocks such as St. Julien, Marianna, Damson, and the scion roots of Domestica and Japanese varieties. No satisfactory way has been found to distinguish these in the orchard from Myrobalan in the absence of foliage or fruit.

Almond and peach roots are much alike in surface color; various shades of light orange or buff[5] when young, though in age they may become pink, red, or dark under various soil conditions. Peach more commonly becomes dull red, and almond brown or reddish brown. The most outstanding feature distinguishing peach roots from almond or from any of the others is that after the trees have been in the orchard more than a year or two the inner bark tissues of the crown and basal portions of larger roots of the peach turn to a distinctly yellowish[6] color, whereas none of the others of this group have this color. Merely gouging the bark below the union will usually determine whether or not the rootstock is peach. In unhealthy or very old trees the inner bark tissues may become pink or reddish. However, by shaving the bark at the graft union the yellow color will nearly always be found near the cambium layer.

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[5] Commonly, Ridgway's ochraceous buff and apricot buff.
[6] Approximately, Ridgway's deep colonial buff.

Besides occurring in the roots, the yellow color in the bark apparently occurs in the branches of all varieties of *Amygdalus persica* (including var. *nectarina*), but does not occur in that of roots or branches of *A. davidiana.*

If for any reason the yellow color has become obscured there are several other more or less distinctive characteristics. Almond bark is distinctly thin — being about half as thick as that of peach. The rows of lenticels of peach are usually closer together and are usually about twice as high as those of almond (also of apricot and Myrobalan). Between rows of lenticels the surface of the peach root is more glossy and smooth to the touch than almond. Peach roots branch more freely, are less straight and have more small laterals than almond.

CHERRY ROOTS

In the cherry orchard the determination rests principally upon the color of the inner bark tissues — that of Mahaleb root being white,[7] and upon exposure quickly oxidizing to a cinnamon or cinnamon red[8] color; whereas that of Mazzard and Morello has a faintly yellowish or buff tinge, turning to a dark orange,[9] but much more slowly than the change in case of Mahaleb. The Sweet, Sour and Duke cherry scion varieties all have the buff color similar to the Mazzard and Morello roots. This color difference is not present in nursery trees. It develops a year or more after transplanting to the orchard. To make the test it is only necessary to shave off the outer cork layers at the graft union. If the inner bark tissue below the union is the same color as that of the scion variety, the rootstock is either Mazzard or Morello; but it is Mahaleb if this tissue is white or pink and immediately begins to change color while the tissues above the union do not begin to change for a quarter to half a minute later.

Morello roots can usually be distinguished from those of Mazzard from the fact that sweet cherries greatly overgrow it, and also that it is very prone to send up suckers from between the rows. Our experience with Morello roots is confined almost entirely to a strain known in California as "Stockton" Morello and which is propagated vegetatively by suckers.

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[7] Called to our attention by Dr. T. E. Rawlins.

[8] Ridgway's cinnamon and cinnamon rufous.

[9] Ridgway's xanthine orange.

Preliminary Observations on the Fruiting of Varieties Other Than Grimes on Virginia Crab Stocks

By J. A. McClintock, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

WITHIN recent years fruit growers have experienced serious losses of bearing trees as a result of extreme winds or low temperatures. Such experiences have raised questions regarding the rootstocks on which these damaged trees were growing. Examinations by fruit growers and research horticulturists have shown that varieties on French Crab stocks suffered most severely, while those on Virginia Crab and Hibernal suffered the least from storms such as the one which occurred in the midwestern states on November 11 to 15, 1940.

Knowing that such adverse weather conditions may recur at occasional intervals, fruit growers accordingly are giving more thought to the problem of what stocks to use for apple trees to be set. Hardy stocks such as Hibernal and Virginia Crab have proved their worth in withstanding wind and low temperatures; therefore, these stocks appeal to fruit growers. In many cases, however, growers, when replanting, desire to take advantage of promising new varieties or red fruited bud-sports of older varieties. This raises the question as to whether these varieties will grow and fruit as well on Virginia Crab or other hardy stocks as did the older varieties such as Grimes, as reported by Lantz (1) and McClintock (2).

Tests in Iowa (3) and Indiana (4) indicate that for Stayman and at least one of its red-fruited sports, Virginia Crab is not a satisfactory stock. Further evidence presented by Maney (3) that Winesap is "half dwarfed, somewhat weakened, and not productive" on Virginia Crab stocks might lead to the supposition that the Winesap group will not grow successfully on this stock. However, the favorable growth of Turley, a Winesap seedling, on Virginia Crab, both in Iowa (3) and Indiana (4) indicates that it is not safe to generalize on stock-scion affinity. Each variety must be judged on the basis of its growth and yield records. Data published by Hilborn and Waring (5) add to available evidence on varietal affinity to hardy stocks, and indicate that these stocks will probably give the same good results in the Eastern States that they have in the Mid-West. A further factor which should not be overlooked, Maney (3), is that French Crab seedlings are among the poorest stocks for Jonathan from the standpoint of fruit yields, a fact well recognized in Grimes on French Crab (2). As experimental data accumulate it is probable that many of the leading commercial varieties will be found to grow and produce better yields on some of the vigorous hardy stocks than they have on French Crab seedlings.

As no one stock has been developed which has proved uniformly good for all varieties, it seems desirable to publish data as they are accumulated in various parts of the country to aid growers in deciding which stocks to use for their desired varieties.

In 1936 plantings were made at the Purdue University Agricultural Experiment Station, Lafayette, Indiana, to obtain records on varieties suitable for Indiana conditions. In 1938 results were published (4) indicating that Golden Delicious, Turley, McIntosh, Gallia, and Starking made more vegetative growth than did Grimes when top-worked on Virginia Crab. Richared, and Blackjon produced somewhat less growth than Grimes, and Blaxtaman made poor growth.

While vegetative growth is essential to good yields, it is not true that the most vigorous growth always yields the most profitable crops of fruit. The growth of these top-worked trees is, as yet, insufficient to provide accurate fruit yield records; however, sufficient data are available to indicate the age at which they come into bearing.

Of the varieties in this test-planting of 1936 Golden Delicious was the first to bear. It produced some fruit in 1939 and has continued to produce increasing yields in 1940 and 1941. Turley and Gallia produced some fruit in 1940 and fruited again in 1941. Grimes, McIntosh and Blaxtaman produced their first fruits in 1941. Blackjon, Richared and Starking have produced no fruit to date.

Yields per tree are not yet large enough to give worth while data on the influence of the stock on the number of fruits per tree of each variety, but in general, the fruits produced to date are characteristic of fruits on young trees, that is, larger than average for the variety, but the color is typical. The red bud-sports develop their fruit color earlier than the parent varieties.

At this stage in the study of apple stocks, experimental evidence does not justify positive statements regarding the best stock for each commercial variety, but there are sufficient data to indicate that both Hibernal and Virginia Crab stocks are hardy, that they have good root-systems, strong trunks and wide angled crotches and that they are congenial to most of the cultivated varieties used commercially in the United States. Thus far we do not have sufficient data to indicate whether Hibernal is equal to Virginia Crab in resistance to collar rot, caused by *Phytophithora cactorum*. Recent observations, however, indicate that the natural resistance of the Virginia Crab stock is not transmitted to the scion variety; therefore, it seems important at this stage of the stock investigations to stress the point that if growers wish to get the best service from Virginia Crab as a stock they should use the Virginia Crab trunk and scaffolds to avoid crotch splitting, and collar rot infection of susceptible varieties. Top working into Virginia Crab trunks by various methods of grafting has not proved as satisfactory as budding or grafting into the scaffolds.

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Overgrowth Produced by Edible Cherry on Sargent Cherry (Prunus Sargentii Rehd.)

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THE Sargent cherry (*Prunus sargentii* Rehd.) is considered to be the hardiest and most vigorous of the many Japanese flowering cherries. At the United States Plant Introduction Garden at Glenn Dale, Maryland, its seedlings are likewise very vigorous and fast growing, while both the mature trees and their progeny have been singularly free from leaf spot and gumming. Such a combination of desirable traits suggested the possible suitability of this species as a rootstock and trunk-former for our edible cherries, since varieties of *P. serrulata* Lindl. are commonly worked on seedlings of *P. avium* L. Apparently there are no previously recorded data concerning the graft affinities of our edible forms with *P. sargentii* although Sargent seedlings have been recommended and used satisfactorily as rootstocks for some of the flowering cherries.

In August 1939 buds of Bing, Schmidt, Seneca and Windsor and a sour cherry, Triaux (P. I. 123754), were topworked into the current growth of 2-year-old *Prunus sargentii* seedlings. Each variety was budded on 50 seedlings in a randomized block arrangement of 10 replications. Diameter and total growth measurements were recorded at the end of each growing season.

Aside from the varying amounts of bud failures and losses suffered by all varieties except Bing, the early and continued production of overgrowths has been a matter of much interest. A large portion of Bing and Triaux budlings were showing distinct evidence of this condition by July, 1940, and they were followed very shortly thereafter by individual cases in other varieties. That this condition of overgrowth is progressive is evidenced by the data summarized in Table I. Not only was there an increase in 1941 over 1940 in the number of budlings having cross-sectional areas greater than their respective

TABLE I—Cross Section Areas of Various Cherry Varieties and of the Sargent Cherry Seedlings on Which They Had Been Worked

Variety	Trees Alive Oct, 1941 (No.)	Budling			Seedling Below Bud				Cases of Budling Exceeding Stock	
		Cross-section Areas in			Cross-section Areas in					
		Oct, 1940 (Mm^2)	Jul, 1941 Percentage of Oct, 1940	Oct, 1941 Percentage of Oct, 1940	Oct, 1939 (Mm^3)	Oct, 1940 (Mm^3)	Jul, 1941 Percentage of Oct, 1940	Oct, 1941 Percentage of Oct, 1940	Oct, 1940 (Per Cent)	Oct, 1941 (Per Cent)
Bing	46	223	214	260	64	146	193	219	91	100
Schmidt...	27	148	215	250	71	131	182	202	56	93
Seneca....	24	144	193	241	70	136	167	195	50	83
Windsor...	35	160	212	254	72	147	183	202	49	80
Triaux....	11	145	222	267	49	112	201	223	73	100

seedlings, but there was also a progressively greater increase in the cross-sectional areas of the budlings themselves.

Fig. 1 shows the type of overgrowths that have been produced generally throughout the planting. Though Bing has shown a tendency toward a somewhat greater amount of overgrowth than that made by the other sweet cherries, it has at the same time been the most vigorous grower of the group.

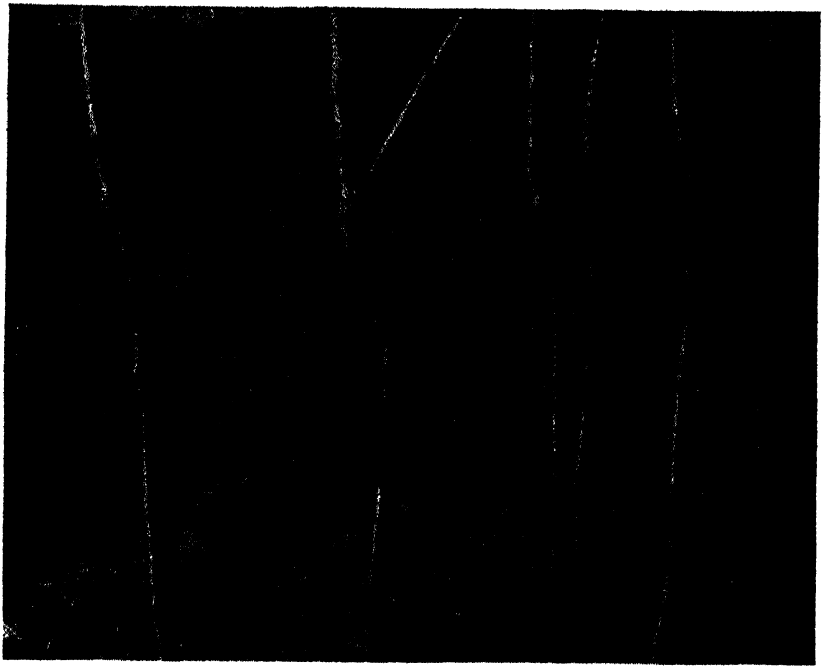

FIG. 1. Overgrowth produced by sweet cherry budded on *Prunus sargentii* Rehd. The tree to the left is budded to Windsor; the others to Bing. (Photographed by Claude Hope.)

Whatever may be the physiological relationships involved in this graft combination, it is clear that the overgrowths produced are so great that trees so constituted will become progressively mechanically weaker and therefore short-lived, and use of seedlings of Sargent cherry as stocks for sweet or sour cherry seems inadvisable.

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Methods of Handling Elberta Peach Pits in Relation to Nursery Germination

By W. H. UPSHALL, *Horticultural Experiment Station, Vineland Station, Ontario*

ONTARIO canning companies regularly use large quantities of Elberta peaches. This makes available to nurseries a cheap and convenient supply of peach pits for rootstock purposes and consequently they have been used to a very considerable extent. Usually the results have been quite satisfactory, though sometimes the stand of seedlings has been disappointing. Various germination experiments with Elberta pits at the Ontario Horticultural Experiment Station during the past 12 years have yielded some results of possible value to nurserymen and plant breeders in obtaining a higher and more consistent germination. In planning these experiments, consideration has been given to the fact that few nurserymen have ready access to suitable storages for after-ripening peach pits and that they wish to avoid artificial cracking, if possible.

EFFECT OF DRYING PRIOR TO BEDDING

Most Ontario nurseries prefer to plant 1-year-old pits. There is however a diversity of opinion concerning the best way to keep them for this time interval. Some nurseries dry the pits for a few weeks and then put them in soil in a shallow bed where normal outdoor conditions prevail. The effect of a 6-weeks period of drying prior to bedding, upon subsequent germination, has been studied for a 3-year period. The results are presented in Table I. These data show that drying of the pits prior to bedding gave an increase in germination over non-drying only one year out of three and appears, therefore, to be an operation which may well be eliminated.

COMPARISON OF FIRST AND SECOND YEAR GERMINATION

In Ontario nursery practice, Elberta pits are usually left in a bed for a complete year before planting. Gardner and Marth (2) have reported one trial in which non-shelled[1] peach pits of some varieties

TABLE I—COMPARISON OF OUTDOOR DRYING FOR 6 WEEKS WITH IMMEDIATE BEDDING OF FRESH ELBERTA PEACH PITS IN THEIR EFFECTS UPON SUBSEQUENT GERMINATION

	Dried 6 Weeks Per Cent Germination*			Kept Moist Per Cent Germination*		
	First Season	Second Season	Total	First Season	Second Season	Total
1934 pits	2	5	7	3	9	12
1935 pits	0	13	13	0	8	8
1936 pits	21	0	21	23	3	26

*100 non-shelled pits per treatment per year.

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[1] Throughout this paper the commercial term "shell" is used in preference to the botanical term "endocarp" because it lends itself better to grammatical forms.

(Elberta not included) germinated better in the second than in the first season. The comparative germination of Elberta pits for the first and second seasons after planting, over a 12-year-period, is presented in Table II. These results show that, in 9 years out of the 12, non-shelled Elberta pits have germinated better in the second season, and in fact, in 6 years there was no germination in the first spring. Conversely, in 3 of the years, all or almost all of the viable pits germinated in the first spring. In these years the bedded pits proved to be worthless for nursery purposes as 1-year-old pits, few additional seeds germinating. These results show the need for a regular examination of the bedded pits for condition of the embryos. One hundred pits taken at random should be cracked and only those having embryos of white internal colour should be considered as potentially viable. The pits should be examined just before the canning season, *i. e.* almost a year after bedding when, if the embryos are found to be worthless, there will be opportunity to obtain a double supply of fresh pits, one-half of which could be cracked in the first spring to provide seedlings for that year and one-half left bedded until the next fall.

TABLE II—YEARLY GERMINATION OF FALL PLANTED NON-SHELLED ELBERTA PEACH SEEDS

Pits of the Crop of	Per Cent Germination*		
	First Season	Second Season	Total
1928	9	17	26
1929	14	30	44
1930	22	2	24
1931	22	0	22
1932	0	36	36
1933	0	35	35
1934	0	15	15
1935	0	8	8
1936	21	0	21
1937	1	38	39
1938	5	18	23
1939	0	51	51

*100 pits per year.

EFFECT OF SHELL UPON GERMINATION

Over a 7-year-period removal of the shell by cracking resulted in an appreciable germination (22 to 42 per cent) in the first spring (Table III). This indicates that a high proportion of the potentially viable seeds had after-ripened sufficiently in the bed during the first winter but, in most years, the shell exerted some effect to keep them from germinating. This result is in agreement with the findings of Dorsey (1) and Haut (3). In years when the shell interferes with germination the effect is reduced by the second spring to a point where commercially good germination results are attainable.

The first year germination of 14 and 22 per cent respectively for non-shelled seeds in the first two years of these seven is not sufficient argument for the omission of cracking nor is it possible with present

TABLE III—TIME OF GERMINATION OF NON-SHELLED AND SHELLED ELBERTA PEACH SEEDS

Pits of the Crop of	Time of Planting	Treatment	Per Cent Germination*		
			First Season	Second Season	Total
1929	Fall	A, non-shelled	14	30	44
	Fall	B, shelled†	30	0	30
1930	Fall	A	22	2	24
	Fall	B	30	0	30
1931	Spring	A	1	12	13
	Spring	B	42	0	42
1932	Spring	A	0	43	43
	Spring	B	39	0	39
1933	Spring	A	0	30	30
	Spring	B	24	2	26
1934	Spring	A	0	5	5
	Spring	B	28	0	28
1935	Spring	A	0	20	20
	Spring	B	22	0	22

*100 seeds in each lot. The differences in total germination between the two treatments for any given year may have resulted from freezing, insect or disease injury.

†Seeds were shelled immediately before planting.

knowledge, to predict when the pits will crack well by natural means in the first spring. At this time it seems that a nurseryman who depends on Elberta pits for rootstock purposes must be prepared to do hand or machine cracking of pits occasionally. Haut (3) has pointed out the importance of protecting after-ripened embryos from desiccation which might reduce viability and force them back into a rest period.

FALL VS. SPRING PLANTING OF SHELLED AND NON-SHELLED SEED

In 1929 and 1930 shelled seeds were planted only in the fall. In each year a 30 per cent germination resulted the following spring. However, in the next two years fall planting of shelled seed resulted in almost complete failure while non-shelled seeds gave a total germination of 22 and 36 per cent. On the other hand, during five consecutive years newly-shelled seed planted early in the spring gave good commercial stands. It may be concluded therefore, that spring planting is definitely preferable to fall planting of shelled seed.

The non-shelled year-old pits may be planted in the fall or early spring. In our tests results have not been consistently in favour of one or the other. However, fall planting is more desirable from the standpoint of labour availability in the nursery. At Vineland, pits often begin to crack late in April and if there is an appreciable proportion of germinating seeds at planting time not only is planting done more slowly but there is great danger of injury to the growing seeds. Early spring planting might be preferable to fall planting only where the field is so exposed that the snow might blow away allowing deep and hard freezing of the soil and pits planted therein. Dorsey (1) found that a temperature of 0 degrees F for 48 hours killed nearly all of one lot of shelled Elberta seed.

Whenever good one-year-old pits are available nurserymen will prefer to use them because they give good commercial stands without resort to cracking. In these germination tests it has been repeatedly observed also that the year-old pits germinate more quickly and more uniformly than pits of the previous season's crop, and consequently are a better grade of seedlings at budding time.

SUMMARY

In 9 years out of 12, non-shelled Elberta peach pits, bedded in soil for a year, then planted in the nursery row, gave fair to good commercial stands of seedlings the following spring. In the other 3 years all or nearly all of the viable pits germinated in the bed the first spring leaving wholly or largely worthless pits. In such instances a satisfactory stand of seedlings may be obtained the following spring by resort to cracking, in mid-April, of pits of the previous season's crop which had been put in a soil bed as soon as the flesh was removed.

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An Injurious Effect of Peach Juice on Germination of the Seed

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WITH peach breeding, a high percentage germination of the seeds is desirable, since only one seed is obtained from each cross-pollinated fruit. It has been shown (1, 2, 3) that various factors influence germination of the seed after the pit has been removed from the flesh. Previously Haut (1) and Haut and Gardner (2) pointed out the injurious effect of pulp disintegration on the viability of the seed. The present investigation was conducted to see if the injurious factor was associated directly with fermentation of the pulp or if it was a destructive agent in the peach juice and whether rinsing the seeds in water would tend to decrease the injury.

MATERIALS AND METHODS

In the fall of 1939 fruits of Salberta and a Late Crawford seedling were picked from the trees, taken to the greenhouse, and divided into two lots for each variety. One lot of about 6 bushels of fruit of each variety was put in a small pile on a ground bed under glass and permitted to decompose. At the end of 5 days half the pits were removed from near the bottom of each pile, washed free of pulp, and set aside to dry at room temperature. At the end of 10 days the remainder of the pits were removed from the rotted pulp, washed clean, and dried. A temperature reading was taken each day in the pile and is shown in Table II. In the second lot of fruit the pits were separated from the pulp as soon as the peaches were picked. Six bushels of the fresh pulp were mashed and put in a tub as a source of fermented peach juice. After 6 days the juice was strained from the pulp and about 3-gallon portions put into two glazed crocks. The pits that had previously been saved from the fresh fruit were placed in the juice. Half the pits were left in the juice for 2 days and half for 7 days, at which times they were removed and placed in running water to rinse. Half of each lot was rinsed for 2 days and half for 7 days. At the time the pits were placed in the juice to soak equal numbers were placed in clear water and soaked for 2 and 7 days. Hence, 10 treatments were used, as shown in Table I, plus a check that consisted of pits taken directly from the fresh pulp, and left unsoaked.

The pits were stratified uncracked in flats containing sand and after-ripened 95 days at 40 degrees F. The pits were planted in the flats in such a way that they could be germinated without being handled following after-ripening. Four replications per treatment were used, with 25 seeds in a replicate, and since two varieties were used, there were 200 seeds available in each treatment for comparison. Analysis of variance was used on the data.

RESULTS

The results are summarized in Table I. Seeds from fruit rotted for as long as 10 days in the pile were nearly all non-viable. Haut (2) has shown a similar effect. The few that grew in these tests could have been from pits near the edge of the pile. Pits soaked in peach juice 7 days were apparently injured as severely as those rotted in the pile 10 days. Pits from fruits rotted in the pile 5 days or soaked in juice 2 days were less severely injured and showed a varietal difference in response to the treatments.

TABLE I—TOTAL NUMBER OF SEEDLINGS OBTAINED IN EACH TREATMENT FROM 100 PEACH PITS OF SALBERTA AND LATE CRAWFORD SEEDLING

Pit Treatment*	Salberta	Late Crawford Seedling	Total Both Varieties
1. Check, no treatment	66	94	160
2. Pulp removed; pits in water 2 days	70	95	165
3. Pulp removed; pits in water 7 days	71	91	162
4. Left in rotting pile 5 days	49	87	136
5. Left in rotting pile 10 days	12	19	13
6. 2 days in peach juice, unrinsed	53	76	129
7. 2 days in peach juice, 2 days in H_2O rinse	71	49	120
8. 2 days in peach juice, 7 days in H_2O rinse	71	45	116
9. 7 days in peach juice, unrinsed	19	19	38
10. 7 days in peach juice, 2 days in H_2O rinse	17	22	39
11. 7 days in peach juice, 7 days in H_2O rinse	9	13	22
Total	508	610	
Difference needed for significance at 19:1†			
For varieties	48.2		
For treatments			20.5
For variety × treatment	14.3		

*Treatments replicated 4 times, with 25 seeds in each replicate.
†Comparison to be made between totals.

Rinsing the pits in running water for 2 or 7 days was ineffective in overcoming the injury sustained by treating the pits with peach juice. On the other hand, soaking untreated pits in water for as long as 7 days was apparently not injurious to the seeds.

TABLE II—RECORD OF TEMPERATURES IN CENTER OF PILE OF DISINTEGRATING PEACH PULP ON A GROUND BED IN THE GREENHOUSE (PULP PUT IN PILE SEPTEMBER 13, 1939)

Date (September)	Time	Temperature in Pile (Degrees F)	Temperature of Air (Degrees F)
14	11:00 a.m.	68	76
15	11:15 a.m.	74	85
16	9:30 a.m.	84	84
17	5:30 p.m.	83	84
18	9:30 a.m.	74	70
19	1:00 p.m.	69	80
20	1:30 p.m.	74	75
22	11:30 a.m.	72	80

DISCUSSION AND CONCLUSIONS

There seems to be an injurious agent present in fermented peach juice that destroys viability of the seeds. The same injurious effect on seed was obtained by permitting the seeds to remain in rotting pulp for 10 days or in fermented peach juice for 7 days. These results are in agreement with Haut's observations, except that the temperature in the pile of fermenting pulp is probably not a factor, as there was no excessive increase in temperature in the small piles of pulp that were used in this experiment.

Because of the injurious effect of overripe pulp on seeds, for best germination the pits should be separated from the ripe pulp as soon as possible after the fruit is picked from the trees.

Preliminary work with this injurious substance on the germination of tomato seeds indicates that it is of a volatile nature and is extractable by ether from peach juice. Work is being continued on this phase of the problem.

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Effect of Stratification and Time of Planting on Germination of Tung Seed[1]

By Ralph H. Sharpe, *U. S. Department of Agriculture, Cairo, Ga.* and Samuel Merrill, Jr., *U. S. Department of Agriculture, Bogalusa, La.*

WHEN planted in the nursery, tung seeds germinate slowly and unevenly. This causes difficulty in early cultivation and frequently results in loss of many plants due to hot weather injury just as they appear above ground. Another result of differences in rate of germination is extreme variation in size of the resulting seedlings. In experimental studies of the progenies of different individual trees, this factor has undoubtedly affected many of the data obtained. Slow germination is probably a primary cause for many seedlings being too small to bud by August 15, even under favorable conditions. It also contributes to the difficulty that growers experience in establishing their orchards by "spot planting" because of failure to get good branching of the trees the first year, although fertility and other conditions are satisfactory.

Several methods of attack on the problems of germination have been made. These include soaking seed in water just prior to planting, treatment of seed coat with acids and other chemicals, removing seed coats and planting with and without treatment with cuprous oxide or semesan, warm and cool storage, dry and wet storage, and others. Small scale tests begun in the spring of 1940 in incubators indicated that stratification is one of the most promising treatments. So far as is known, stratification has not been used by growers in the United States but Li (1) mentions that some growers in China use a form of stratification in that seed are covered with soil and straw in the winter. In the United States, growers commonly store the dry whole fruit and hull it at planting time, or they may hull the seed and store it dry.

To test the value of stratification under field conditions, experiments were set up in the fall of 1940 by the Cairo, Georgia and Bogalusa, Louisiana tung laboratories. At each laboratory, the open-pollinated seeds of six selected trees were divided into four lots. These lots were treated as follows: (a) stratified as whole fruit; (b) stratified as hulled seeds; (c) stored dry as whole fruit; and (d) stored dry as hulled seeds.

Stratification was accomplished by placing the seeds in layers in clean sand under moist but well drained conditions. At Cairo, this was done immediately after harvest, but at Bogalusa, seed that had been harvested in late October and stored dry as whole fruit, was placed under the treatments on December 5. The experiment was set up to test not only the treatments listed above, but also the effect of different dates of planting and any interactions between the treatments and the planting dates. Preliminary tests reported by Merrill, *et al.* (3)

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[1] The authors wish to express their appreciation to Dr. George F. Potter for help with the statistical work and suggestions of an editorial nature.

indicated that the most advantageous planting time is in February.

Four dates of planting, ranging from December 6 to March 17, were used. A split-plot design was used, differing somewhat in detail at the respective stations. At Cairo, six progeny blocks were laid out at random in each replication and the 16 treatment plots (four dates of planting x four treatments) were randomized within the progeny blocks. At Bogalusa, four date of planting blocks were randomized within each replication. These blocks were broken down into four treatment blocks in random arrangement and six progeny plots were randomized within each treatment block.

Two replications were used at Cairo and four replications at Bogalusa. A total of 9,600 seeds were planted by each laboratory, the individual plots comprising 50 seeds at Cairo and 25 seeds at Bogalusa. Counts of seedling emergence were made at regular intervals. The data for an early and a late count at each station, summarized by treatment and date of planting, are given in Table I, but space does not permit presentation of complete data by progenies. Analyses of variance showing the significance of the effects of dates, treatments, progenies, and their first order interactions are given by the data in Tables II and III.

These analyses show that there are highly significant differences between progenies, dates of planting and treatments, and also that

TABLE I—TUNG SEEDLING EMERGENCE AT EARLY AND LATE DATES FOR FOUR SUCCESSIVE PLANTINGS AND FOR VARIOUS STORAGE TREATMENTS (600 SEEDS AT EACH PLANTING DATE FOR EACH TREATMENT)

Planting Dates	Stratified as		Stored Dry as		Totals
	Whole Fruit	Hulled Seed	Whole Fruit	Hulled Seed	
		Bogalusa, April 25			
Jan. 27	180	304	166	173	823
Feb. 13	160	354	144	139	797
Feb. 27	109	290	67	61	527
Mar. 13	67	244	5	20	336
Totals	516	1192	382	393	2483
		Bogalusa, June 20			
Jan. 27	517	539	517	527	2100
Feb. 13	462	521	466	491	1940
Feb. 27	434	527	473	468	1902
Mar. 13	391	515	428	473	1807
Totals	1804	2102	1884	1959	7749
		Cairo, April 26			
Dec. 6	97	227	73	186	583
Feb. 13	53	301	2	60	416
Mar. 3	94	351	1	14	460
Mar. 17	71	358	0	1	430
Totals	315	1237	76	261	1889
		Cairo, May 24			
Dec. 6	310	389	273	384	1356
Feb. 13	286	482	149	275	1192
Mar. 3	285	473	60	173	991
Mar. 17	271	448	10	92	821
Totals	1152	1792	492	924	4360

TABLE II—Analysis of Variance of Number of Seeds Germinated (Plants Emerged, Bogalusa, Louisiana)

Source of Variation	D. F.	Counted April 25		Counted June 20		
		Mean Square	F Found	Mean Square	F Found	F Required
Dates	3	562	11.96	155	31.00	6.99†
Replications	3	140	2.98	2	.40	3.86*
Interaction replications × dates	9	47	—	5	—	—
Total date plots	15					
Treatments	3	1549	73.76	167	33.40	4.38†
Interaction treatments × dates	9	21	1.17	17	3.40	2.94†
Interaction treatments × replications and treatments × replications × dates	36	18	—	5	—	—
Total treatment plots	63					
Progenies	5	419	41.90	704	117.33	3.11†
Interaction progenies × dates	15	15	1.50	12	2.00	1.74*
Interaction progenies × treatments	15	32	3.20	54	9.00	2.17†
Remaining interactions	285	10	—	6	—	—
Total progeny plots	383					

*for P. =.05.
†for P. =.01.

there are several significant interactions. Just as was reported by Merrill, *et al.* (3), seed from different trees show vast differences in rate of germination, and still greater differences in the final number that grow. This is indicated by the fact that the *F* value for progenies for the early-season count at Bogalusa, is very high, but is still higher for the June count and this latter measures the progeny differences in final stand. Contrary to the findings of Merrill and his associates, very early planting, even in December, proved advantageous for unstratified seed. This may be due to the fact that the plantings in 1940 both at Cairo and at Bogalusa were on considerably lighter soil than

TABLE III—Analysis of Variance of Number of Seeds Germinated (Plants Emerged, Cairo, Georgia)

Source of Variation	D. F.	Counted April 26		Counted May 24		F Required at .01 Level
		Mean Square	F Found	Mean Square	F Found	
Progenies	5	1004.8	6.61*	1411.8	14.68	10.97
Replications	1	4266.0	28.7	17900.0	186.07	16.26
Interaction progenies × replications	5	152.0	—	96.2	—	—
Total progeny plots	11					
Dates	3	120.7	3.00*	1134.3	17.67	3.94
Treatments	3	5633.3	140.13	6123.7	95.38	3.94
Interaction dates × treatments	9	306.9	7.63	492.2	7.67	2.56
Interaction progenies × treatments	15	148.1	3.68	90.0	1.40	2.23
Interaction progenies × dates	15	89.7	2.23	54.4	.85	2.23
Remaining interactions	135	40.2	—	64.2	—	—
Total date-treatment plots	191					

*Significant at .05 level.

that used at Bogalusa the previous season. Then too, in 1941, a severe spring drought placed late season plantings at a considerable disadvantage. The interactions of progenies x treatments and progenies x dates indicate that certain progenies are benefited more by stratification or by early planting than are others. It appears that those progenies that are naturally quick to germinate are benefited less than are those that are slow to germinate.

The April counts in particular show that stratification of the hulled seed made them germinate earlier and more uniformly. Stratifying of the whole fruit was much less effective, the results being but little different from those with fruit or seed stored dry. The difference due to stratification is graphically illustrated in Fig. 1, which compares the germination of stratified and nonstratified hulled seed at different planting dates. This graph also brings out the interesting interaction that stratified seed benefit less from early planting than non-stratified seed. The reason for this is that apparently early planting accomplishes somewhat the same thing as stratification. Beginning with the February 13 planting, however, the seed which was hulled and stratified consistently germinated earlier than that from any of the other treatments. The major factor affecting this is believed to be due to the difference in the intake of water, but other factors may have been operative. In this connection, it should be pointed out that at the Cairo laboratory, the stratified seeds were probably subjected to better aeration and slightly warmer temperatures during the period of stratification than after being planted in the field. Hence, the later plantings of stratified seed would have been subjected for a longer period to a favorable combination of moisture and temperature conditions than

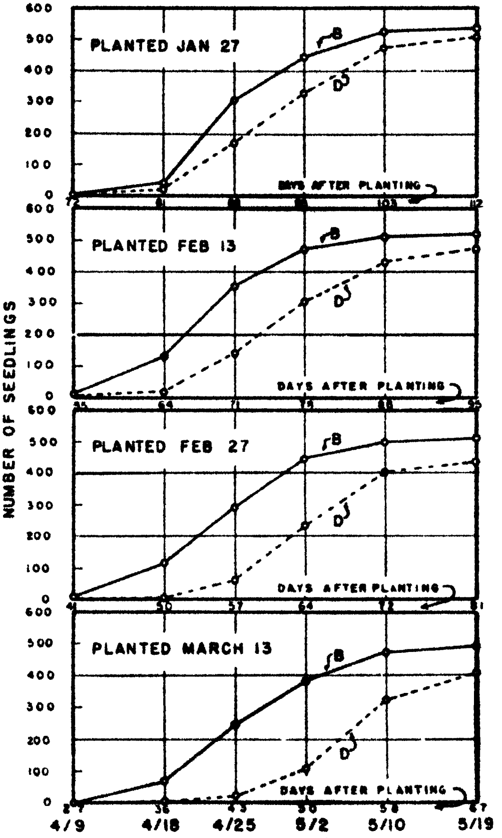

FIG. 1. Effect of stratification on rate of germination of hulled tung seed. B, stratified; D, stored dry (Bogalusa, Louisiana, 1941).

were the early plantings and should have germinated faster. This actually happened. On April 26, 709 seedlings from stratified hulled seed planted March 3 and 17 were up, as compared to 528 from similar seed planted December 6 and February 13.

Separate experiments conducted in the laboratory help to point out further the relative importance of water intake and the temperature at which seed are stratified. With seeds of many temperate climate fruits such as apple, peach, and others, it is recommended that stratification be done under cool conditions (2). This is thought to aid in after-ripening of the seeds. In tung, however, it was thought that stratification at cool temperatures might not be necessary. In this experiment, seeds were stratified in a room where temperatures varied from approximately 40 to 65 degrees F and in a refrigerator at approximately 34 degrees F. Seed coats were then removed and sub-lots of the seeds were germinated in incubators at several constant temperatures ranging from 75 to 90 degrees F. A summary of the results is given by the data in Table IV, together with moisture determinations of the kernels of similarly stored seeds. These data show that the warmer stratification temperature has significantly aided early germination, and also that the percentage of seeds that germinate is increased with the longer periods of stratification. These differences are obviously not due to the moisture content of the seed at the time they are placed in the incubator. It was not possible to note any swelling of the hypocotyl during storage, but it is probable that other processes associated with germination such as enzyme activation and gaseous exchange are begun during stratification at the higher temperature and that these operate to cause more rapid germination when seeds are placed under favorable temperature conditions. Since many progenies show only partial development of the embryos at time of fruit harvest, it is also possible that further development of embryos occurs in tung seeds during the period of stratification.

TABLE IV—EFFECT OF STRATIFICATION UNDER TWO CONDITIONS ON GERMINATION OF SHELLED TUNG KERNELS, AT TEMPERATURES ABOVE 75 DEGREES F (80 SEEDS FOR EACH CONDITION AT EACH PLANTING DATE)

Place of Stratification	Date of Planting	Moisture in Kernels (Per Cent)	Germination During	
			5 Days	25 Days
Room (40 degrees to 65 degrees F) . . .	Dec 4	18	8	63
	Dec 31	27	34	78
	Jan 30	26	46	79
Refrigerator (34 degrees F).	Dec 4	23	6	45
	Dec 31	26	12	69
	Jan 30	24	8	70

At Bogalusa, measurements of seedling diameter and height made at the close of the season, indicate that seedlings from the stratified seed failed to maintain the lead they gained by early germination. Had they been planted in separate blocks, it would have been possible to cultivate and side dress them with fertilizer earlier than the rows from non-stratified seed. This would have resulted in better weed control and probably in larger size of seedlings at budding time. Because the seeds subjected to various treatments were randomized in the nursery, this advantage was not secured. The experiments at Cairo were not continued through the season and hence, no measurements of the final size of the trees were possible.

SUMMARY

Stratification of hulled tung seed was of definite aid in hastening and improving germination. It was of especial value with seed from certain parent trees that naturally germinate slowly. Stratification of the whole fruit resulted in much poorer and slower germination than when the seeds were hulled and then stratified.

Planting in January rather than in March hastened and improved germination in the case of dry-stored seed, but did not particularly benefit stratified seeds. By use of stratification, plantings may be delayed until the advent of warm weather with consequent reduction of time between planting and germination dates, thus allowing better weed control.

Better results are obtained by stratifying at moderately cool temperatures than by stratifying in cold storage.

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Root-Inducing Substances Effective on Apple Cuttings Taken in May

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ALTHOUGH no practical application has been made of the root-inducing substances for propagating commercial varieties of apples, the results obtained in our laboratory since 1936 indicate that such an application is feasible. During the years 1936 and 1937 solutions of indolebutyric acid induced rooting in leafy apple cuttings taken between May 14 and June 6 and in hardwood, leafless cuttings taken in November and December. A concentration of 40 mg/1 of indolebutyric acid proved optimum for a 24-hour treatment of leafy cuttings planted in sand. A 4-hour treatment with 80 to 320 mg/1 was effective on hardwood cuttings buried in peat moss after treatment and held at 70 degrees F. Dipping the basal ends of hardwood cuttings in solutions containing 4 to 10 mg/cc was also effective (1). Powder preparations containing 10 to 25 milligrams of crystalline indolebutyric acid per gram of talc (commercial grades) proved effective when tried in 1939 (1). In the present 1941 tests, specially prepared finely-ground preparations of root-inducing substances furnished by Merck and Co. Inc., Rahway, New Jersey, proved highly effective on six varieties of apples.

ROOT-INDUCING PREPARATIONS

The following powder preparations were used: 1, 2, 3, 8 and 12 milligrams of IB (indolebutyric acid) per gram of talc; 1, 2, 4 and 8 mg/g NA (naphthaleneacetic acid); and mixtures of equal quantities of IB and NA with total concentrations of 2, 4 and 8 mg/g. Solution treatments and combinations of solution and powder treatments were administered to cuttings taken after June 3. IB and KIB were used in concentrations of 40, 50, 100, 200, and 400 milligrams per liter for periods of 24, 20, 16, 8, 4, and 2 hours, respectively. Basal ends of cuttings were also dipped into concentrated alcoholic solutions of IB and water solutions of KIB (4–20 mg/cc), and some of these cuttings were given an additional treatment with the powder preparations previously mentioned.

RESULTS

Cuttings of McIntosh, Grimes Golden, Northern Spy, Rhode Island Greening, Stayman Winesap, and Yellow Transparent which were treated with root-inducing substances, exhibited relatively high percentages of rooting in 5 to 6 weeks when the cuttings were taken during the period May 9 to June 3. Representative rooting responses for control and treated cuttings planted in a sand medium in greenhouse benches are shown in Figs. 1 and 2. In contrast, similarly treated softwood cuttings exhibited lower percentages of rooting when planted in a mixture containing one-fourth peat moss, by volume, and the remainder builder's sand (Table II). Likewise, with one exception mentioned later, cuttings taken June 10 and thereafter exhibited little

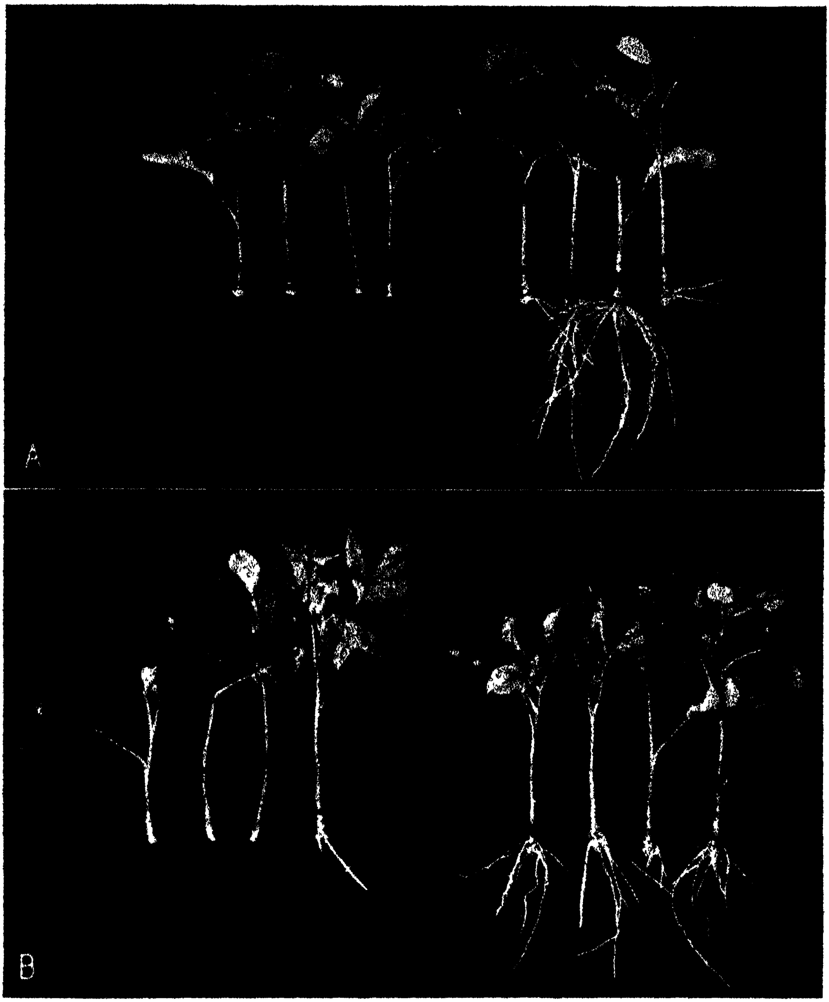

FIG. 1. Rooting of apple cuttings taken in May. Photographed after 46 days in sand. Left, control cuttings; right, cuttings treated with 8 milligrams indolebutyric acid per gram talc. A, McIntosh; B, Northern Spy.

or no rooting regardless of whether they were planted in sand or in mixtures of sand and peat moss.

A standard series of nine treatments consisted of three concentrations of each of the three preparations but the same concentrations were not always used. The series of nine treatments shown in Table I was used most frequently. As an example of the results obtained with one series of nine treatments, the percentage rooting for cuttings of Rhode Island Greening taken May 9 were as follows when examined June 12: IB–8 mg/g 100 per cent, IB–3 100 per cent, IB–1 0.0 per cent, NA–8 25 per cent, NA–4 25 per cent, NA–1 25 per cent, IB+NA–8 0.0 per cent,

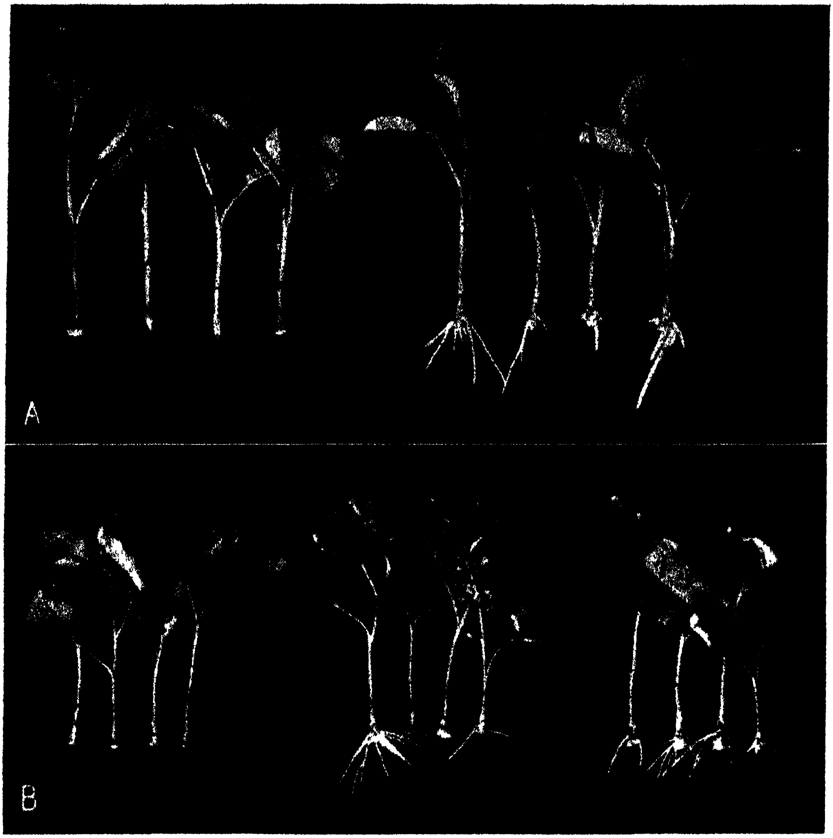

Fig. 2. Rooting of apple cuttings taken in May. Photographed after 36 days in sand. A, Stayman Winesap: left, control; right, treated with 8 mg/g indolebuytric acid in talc. B, Rhode Island Greening: left to right, control; treated with 3 mg/g indolebutyric acid; treated with 8 mg/g indolebutyric acid.

IB+NA–4 50 per cent, IB+NA–2 0.0 per cent. The average value for the three best treatments (100, 100 and 50 per cent) is 83 per cent (first line, Table II). In a similar manner the average for the three best treatments in 12 series of 9 treatments each was 62 per cent. Thus the value of 62 is the average percentage rooting for the 36 best individual treatments out of a total of 108 treatments applied to cuttings of the six varieties between May 9 and June 3. All three preparations were effective in the range of 4 to 8 mg/g, but IB and mixtures of IB and NA induced optimum rooting more frequently than NA (Table I). The mixtures were generally effective over a wider range (2 to 8 mg/g) than either NA (4 to 8 mg/g) or IB (3 to 8 mg/g). Optimum treatments induced from five to eight roots per cutting. Control cuttings did not root except in the case of one lot of Northern Spy (Fig. 1, B). There were 12 control lots for each of six varieties.

TABLE I—RELATIVE EFFECTIVENESS OF DIFFERENT ROOT-INDUCING PREPARATIONS ON APPLE CUTTINGS*

Substance	Conc. Mg/G Talc	Rank According to Per Cent Rooted Cuttings			Totals
		First	Second	Third	
IB	8	7	3	1	11
IB	3	1	3	0	4
IB	1	0	0	0	0
NA	8	2	2	0	4
NA	4	3	0	1	3
NA	2	0	0	0	0
IB+NA	8	3	0	1	4
IB+NA	4	1	3	2	6
IB+NA	2	0	1	1	2

*Data based on the three best treatments per test, the highest percentage rooting in a test being ranked as first, the next highest as second, and so on.

The effectiveness of the optimum treatments generally decreased with increasing age of the cuttings, even during the month of May, but the relative rate of decrease in effectiveness varied with the variety (Table II). Increasing the concentration of root-inducing substances in powder preparations did not cause an increase in rooting of cuttings taken after June 3. For cuttings taken after June 3 rooting occurred only in the case of solution treatments with IB (40 mg/l for 22 hours) applied to cuttings of McIntosh June 21. The percenatge rooting on August 19 was 33, 50, and 68 per cent, respectively, for three lots planted in mixtures containing one-fourth peat moss, by volume, and the remainder sand. The treated cuttings planted in sand failed to root. This is in contrast to the results with May cuttings treated with powder preparations which rooted best in sand.

DISCUSSION AND CONCLUSIONS

These results are similar to those previously reported from this laboratory for hybrid lilac (2). Although rooting media containing German, Canadian, or Maine peat mosses were detrimental to the young cuttings of apple taken during the middle of May, this was not true for the cuttings taken the first part of June and thereafter. However, in order to obtain consistently high percentages of rooting it is recommended that a sand medium be used, particularly if the cuttings have been treated with powder preparations of root-inducing substances. The detrimental effect of peat moss on softwood cuttings treated with root-inducing substances is not confined to the apple. Treated cuttings of other species and genera rooted better in sand than in mixtures containing one-fourth to one-half peat moss by volume. In some cases this applied to cuttings made from more mature wood. Generally, the differences were more pronounced on cuttings treated with powders than on those treated with solutions. Control cuttings were usually less affected than treated cuttings. However, the detrimental effect of peat moss applies to special cases, particularly to very young softwood cuttings, and is not to be considered as applying to cuttings in general. For example, treated cuttings of both apple and

TABLE II—SOME FACTORS WHICH INFLUENCE THE ROOTING OF APPLE CUTTINGS TREATED WITH ROOT-INDUCING SUBSTANCES

Date Cuttings Taken	No. Days	Type of Cutting*	No. of Treatments**	Rooting Medium	Average Per Cent Rooted		
					All Treatments††	3 Best Treatments	Best for Each of 3 Preparations‡
				Rhode Island Greening			
May 9	33	A	9	Sand***	36	83	58
May 9	33	A	9	¼ mixture†	0	0	0
May 14	47	A	9	Sand	22	50	42
May 14	47	A	9	¼ mixture	0	0	0
Jun 3	39	A	5	Sand	20	50	33
Jun 3	39	B, C	8	Sand	50	83	68
Jun 10 to Aug 22	42+	A, B, C	77	Sand and ¼ mixture	0	0	0
				McIntosh			
May 9	47	A	9	Sand	20	58	42
May 9	47	A	9	¼ mixture	3	8	8
May 27 to Jun 18	42+	A	16	Sand and ¼ mixture	0	0	0
Jun 21	56	D	1‡‡	Sand	0	0	0
Jun 21	56	D	3‡‡	¼ mixture	50	50	—
Jun 26 to Jul 18	42+	A, B, C, D	86	Sand and ¼ mixture	5	—	—
				Grimes Golden			
May 21	43	A	7	Sand	37	67	67
May 21	43	A	7	¼ mixture	25	50	50
Jun 3	58	A	10	Sand	26	47	47
Jun 10 to Aug 27	58	A, B, D	29	Sand and ¼ mixture	3	—	—
				Northern Spy			
May 13	41	A	9	Sand	49	75	75
May 13	41	A	9	¼ mixture	11	33	25
				Stayman Winesap			
May 9	38	A	10	Sand	53	89	83
May 13	41	A	9	Sand	6	17	17
May 13	41	A	9	¼ mixture	0	0	0
May 21 to Jul 9	42+	A, B, D	21	Sand and ¼ mixture	0	0	0
				Yellow Transparent			
Jun 3	37	A	9	Sand	39	83	83

*A = Entire current season's shoot (4 to 7 inches long) cut through rings at base.
B = Tip cuttings from shoots 7 to 12 inches long.
C = Basal cuttings from shoots 7 to 12 inches long.
D = More mature than A, and basal cut ¼ to ½ inch above rings.
**Four to five cuttings per treatment.
***Medium-coarse, light-colored builder's sand from Northport, Long Island, N. Y.
†A mixture composed of ¾ sand and ¼ peat moss by volume.
††Does not include non-treated or talc controls, of which there were altogether 72 lots.
‡Average of the best treatment with IB, NA, and mixture of IB and NA.
‡‡Solution treatments.

lilac which are slightly more mature than the very young softwood stage, which is most suitable for rooting, may root as well or better in a one-fourth peat moss mixture than in sand, but in the latter case the percentage of rooting is generally lower and the results less consistent. Other cases in which the rooting medium becomes an important limiting factor for treated cuttings will be described more fully in a future report.

Treated cuttings were found to root satisfactorily when the air temperature was about 70 degrees F (unheated greenhouse) during the day and when cheesecloth was laid on the cuttings or was made into an enclosure 2 feet high over the cuttings. Rooted cuttings which had been removed for examination were replanted in the rooting medium (either sand or a one-fourth peat moss mixture) in benches in the greenhouse. After branch roots had formed and the root systems were flexible (about September 1), the cuttings were potted in a light soil containing some of the peat moss-sand mixture. The potted plants were placed in cold frames shaded with low slat where they became well established, including some leaf growth, by November 1. Rooted cuttings handled in this manner in 1936, transferred to nursery rows in the spring of 1937, and finally planted in the orchard in 1939, have made excellent growth, but no comparison has been made with grafted trees of the same age.

The possibility of applying this method of propagation to apple root stocks warrants consideration. However, it should be pointed out that root stock shoots may not be comparable to those on grafted trees, so that some modification of the treatment may be necessary. We have found that cuttings made from young sucker shoots on grafted trees do not root as readily as normal terminal shoots. Furthermore, the secondary summer growth is not comparable to the first growth in spring with respect to its capacity to root.

On the basis of these results apple cuttings should be taken when the shoots are 4 to 7 inches long (in May, Yonkers, New York), treated with an 8 mg/g powder preparation of indolebutyric acid, and then planted in sand in greenhouse benches which are shaded sufficiently to keep the cuttings turgid.

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Use of Nurse Seedlings in Propagating the Pecan From Stem Cuttings

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A METHOD of producing own-rooted pecan trees is desirable for production of trees for experimental purposes and may have practical applications. Hamilton (1) produced pecan trees by stem layering, aided by indole-butyric acid treatment; and Gossard (2) secured good rooting from layers by the same method. Stoutemeyer (3) reported success in rooting pecan stem cuttings. The writer also obtained rooting of such cuttings by a similar method but attempts to grow them into trees were not successful. Shoot growth appeared to exhaust

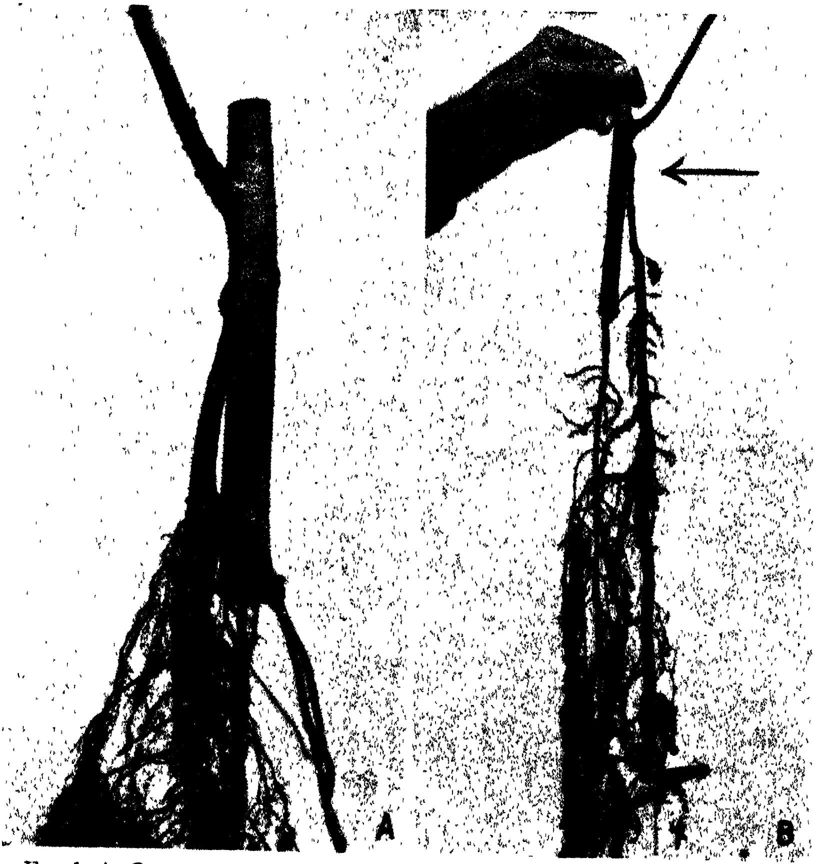

FIG. 1. A, One year's growth of a pecan cutting grafted to a young seedling; B, two years' growth of a cutting grafted to a young seedling. Arrow points to wire girdle on seedling that will gradually sever the seedling roots from the cutting.

the nutrient materials in the cuttings before enough root could form to be effective. This gave rise to the idea of grafting uncallused stem cuttings to seedlings in order to sustain the cuttings until they were well established on their own roots. Progress towards a satisfactory technic to accomplish this object is reported here.

METHODS AND RESULTS

In March and April of 1939, 67 cuttings from 1-year-old pecan twigs were grafted to young pecan seedlings grown in cans in the laboratory. Various methods of grafting were used. These trials resulted in one plant, which is shown in Fig. 1, A. In this case an inverted slot graft was made 20 days after planting the shelled seed, when the seedling sprout was about 3 inches long.

The trials were repeated in March and April of 1940. Union resulted in a large percentage of the grafts, but most of the unions were poor and the seedlings appeared to be unable to support the cuttings. In order to make the desired type of grafts the cutting wood was seasoned before using, that is, it was brought to the stage where the bark would just release. Placing the seasoned cuttings in wet sand at the time of grafting apparently caused a rapid exhaustion of the stored nutrients in the production of shoot growth, so that the cuttings died before a good graft union could form. Accordingly, it seemed likely that greater success might result if shoot growth in the cuttings could be delayed until good graft unions were formed between the cuttings and seedlings. As a means of delaying shoot growth several cuttings were completely covered with melted beeswax so as to prevent water absorption from the soil, and then were grafted to young seedlings. The wax was effective in retarding growth and

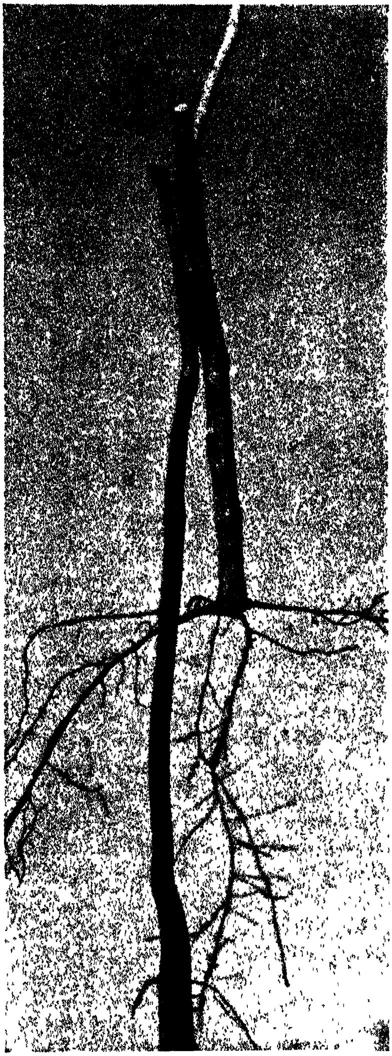

FIG. 2. An illustration of the inarch graft method. Stock is at left and cutting at right.

did not seem to interfere with callus formation at the point of grafting. A 2-year-old plant produced by this method is shown in Fig. 1, B.

In April of 1941 completely waxed cuttings were grafted to nursery seedlings in the field. The inverted slot and inarch methods of grafting were used. The inarch grafts were made by tying a cut area of the dormant stem cutting against a cut area of the growing seedling, and then sealing the points of contact with melted wax. The seedling top was removed after sufficient time had elapsed for callus formation to take place and after the bud on the cutting started growth, Fig. 2.

In making the inverted slot grafts, seedling stems considerably smaller than the cuttings to be used were cut off to a moderately long wedge by a sloping upward cut from one side. The tip of the wedge was trimmed a little by a cut from the opposite side. A strip of bark of the same width as this wedge was cut free and pulled upward on the seasoned cutting, thus forming a slot where this strip of bark was peeled off. The prepared wedge was fitted into this slot, after which the strip of bark was partly cut off and the stock and cutting were tied together. The grafts were first tied with waxed cotton twine in order to pull the stock and scion together and were also tied with fine wire to hold the grafts after the twine had rotted. These grafts were not waxed but most of them were protected against drying by a shield of waxed cloth, which was left open at the lower end. The inarch grafts were much easier to make and were suited to a greater range of sizes of stock and cuttings than the slot grafts. All grafts were made a little above the ground line, the lower ends of the cuttings extending into holes dug in the soil. After the grafts had been made the soil was mounded up to the bud. The cuttings, about 10 inches long, were taken from wood of the previous season's growth and all buds except the one uppermost were removed before waxing.

New shoots were produced by 20 out of 24 cuttings grafted by the inverted slot method and by 7 out of 10 grafted by the inarch method, the average total length of new shoot growth being 19 inches. In order to remove the seedling root from the cutting gradually, after it has served its purpose, the seedling is girdled by tying a wire around the stem. Some of the seedlings were girdled immediately after the cuttings started growth and others have not yet been girdled.

Although 79 per cent of the cuttings grafted to nursery seedlings in the field produced shoots, only 37 per cent of them had rooted by September. No root-inducing chemicals were used on any of these cuttings or those made in 1939 and 1940. There is reason to believe the rooting may be improved by use of such chemicals or by other methods. Therefore, the method of grafting cuttings to seedling, to gain the temporary support and benefit of an established root system seems to offer promise as a means of producing own-rooted pecan trees.

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Humidification and the Rooting of Greenwood Cuttings of Difficult Plants

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THE older manuals on plant propagation present elaborate directions concerning the use of bell jars for cuttings which root with difficulty, but this method has been neglected in modern times because of the attention required in wiping the glasses dry, the high cost, bulk and inconvenience of the apparatus and poor adaptation to large scale propagation. The wide fluctuations in temperature which take place in most propagating structures in summer produce sudden changes in humidity which may cause desiccation and loss of turgor pressure in the cuttings, with consequent loss of ability of the cuttings to root. Often the external appearance of the cutting does not indicate the true severity of the damage.

Increasing the humidity of frames or greenhouses by shading and wetting the walls and floors and the frequent sprinkling of cuttings is an old and well known practice. However, only recently have the various mechanical devices which have been developed for the air conditioning industry been applied to structures for plant propagation. Raines (3) was first to report the use of a spray chamber for the rooting of cuttings. Recently Gardner (2) and Fisher (1) have reported excellent rooting of cuttings under a spray of water applied over the foliage.

At Glenn Dale, Maryland, some preliminary experiments with stationary spray nozzles in continuous operation indicated that prolonged washing of the foliage of the cuttings was undesirable as has been suggested by Raines (4). The rotating spray unit designed by Gardner proved to be superior since the spray was applied intermittently to the cutting bed. This apparatus consisted of a spray head with two small nozzles of the Vermorel type which revolved once each minute and a half under impulsion by a miniature water turbine connected through a one thousand to one reducing gear. This apparatus used about 8 to 10 gallons of water per hour and covered nearly all of the propagating bench surface in a greenhouse compartment 15 by 25 feet. Tests with plants difficult to root, such as *Vaccinium pallidum* Ait., *Chaenomeles lagenaria* (Loisel.) Koidz. var. Rubra Grandiflora, azaleas of the Ghent hybrid and Mollis hybrid groups, sugar maple, and *Symplocos paniculata* (Thunb.) Miq. produced more and better rooting than could be obtained by more conventional equipment. Thus, the claims made for the method of propagation were substantiated in a general way by these preliminary trials.

An apparatus using stationary spray nozzles with solenoid valves operated by an electrical timing mechanism was constructed, but not completed in time to be used in these trials of rooting. A precise control of the duration and frequency of operation was secured by this device. Another installation which was used for the humidification of propagating frames was sufficiently promising to deserve mention.

A low propagation frame in the greenhouse was covered with a heavy grade of Owens-Corning Fiberglas cloth (ESS–12–292) with one edge placed in a long tank of galvanized sheet iron, 3 inches wide and 12 inches deep which formed the back of the frame. The cloth was laid over metal wire supports 3 feet long which sloped downward toward the front edge of the frame. The tank was kept filled with water and once the cloth was moistened, a strong capillary action kept the cloth wet at all times.

The following experiments were conducted using a Walton centrifugal humidifier or atomizer placed several feet above the rooting medium in a greenhouse compartment approximately 15 by 25 feet. The aparatus did not wash the leaves of cuttings with a spray, except those cuttings directly beneath it, but kept the humidity of the air at the saturation point. This device is simple in construction, consisting of little more than a rotating metal turntable coupled directly to an enclosed 30 Watt electric motor. A few fan blades attached to the under surface of the turntable provide a slight draft of air to throw the mist from the humidifier. A small tube extends from the axis of the shaft down to a reservoir of water provided with a float valve at the intake. The top cover was removed in order to obtain the maximum dispersion of the mist. The device was remarkably economical in operation, using only 2 pints of water per hour and consuming only ¼ kilowatt of electricity in the 8-hour period of operation ordinarily used each day. A very fine mist or fog was produced which floated in the air for a long distance. Psychrometric determinations showed that the humidity was kept at saturation even during full noonday sun, except near one of the doors. A slightly larger atomizer would have been desirable for this size of greenhouse. Although the humidifier could be used continuously, operation from about 8:00 a.m. to 5:00 p.m. was sufficient to hold fragile cuttings in good condition. On dark, cloudy days, intermittent operation was satisfactory.

The greenhouse was shaded with slat shades reducing illumination to about 2000 foot candles as measured by a Weston illumination meter at noon on clear summer days. The ventilators were kept closed and the temperature frequently rose to above 100 degrees F without any indication of loss of leaves or other adverse effects on the cuttings. Attempts to reduce the shading caused injury. A porous, well drained rooting medium seems to be advisable and a coarse sand was used in these trials.

As is usual, cuttings taken from very immature wood shriveled and died and cuttings that were very mature dropped their leaves promptly. Nevertheless, the margin of tolerance in both directions was greater with humidification than without it; the gain in the direction of using slightly immature wood was most important since this is the type of wood that roots most readily if it can be saved from collapse. Damping-off and other fungus troubles were not a problem with cuttings taken in a suitable stage of growth. Another advantage of humidification was that thrips and other insects which are sometimes troublesome in closed propagating cases did not develop on the cuttings.

Cuttings of a number of subjects which root with more than average difficulty were placed on open propagating benches in the greenhouse with the humidifier and were compared with similar lots in another compartment with identical shading. Except for *Cyrilla* and *Pterostyrax* the subjects were all tested in a closed propagating frame as well as on an open bench. Twenty cuttings were used in each lot, but limitations of space and cutting material prevented the use of replications on the majority of these subjects. Growth substances were usually found to be advantageous and various concentrations of indole butyric acid in talc were used (designated as IB). Thus a treatment with a mixture containing 1 part of indole butyric acid to 1,000 parts of talc is designated at 1–1000 IB. The results with the most favorable treatments are shown in Table I. The cuttings were always potted and grown on to make certain that normal functional roots were produced.

TABLE I—MAXIMUM PER CENT ROOTING OF VARIOUS CUTTINGS WITH AND WITHOUT HUMIDIFICATION

Subject	Days in Rooting Medium	Best Treatment Used	Per Cent Rooting With Humidification	Per Cent Rooting Without Humidification
Chaenomeles lagenaria (Loisel.) Koidz. var. Rubra Grandiflora.	29	1–250 IB	95	15
Chionanthus retusus Lindl. and Paxt.	135	1–250 IB	65	10
Cornus florida L.	34	1–250 IB	100	40
Corylus hyb. "mildredensis"	50	1–250 IB	55	75
Cyrilla racemiflora L.	56	Talc	30	10
Hamamelis mollis Oliv.	66	1–1000 IB	60	35
Leucothoe axillaris (Lam.) D. Don.	41	1–2000 IB	95	90
Ligustrum compactum Hook. f. and Thoms.	42	1–250 IB	40	0
Neillia longiracemosa Hemsl.	48	1–1000 IB	90	70
Pterostyrax hispida Sieb. and Zucc.	43	1–250 IB	34	30
Stauntonia hexaphylla Decne.	56	1–1000 IB	65	55
Symplocos paniculata (Thunb.) Miq.	61	1–250 IB	30	5
Thladiantha dubia Bunge	28	none	70	65

The data shown in Table I indicate that mechanical humidification was advantageous in the rooting of practically all of the more difficult subjects. Aside from increases of rooting, the leaf retention was superior in the lots under mechanical humidification.

The advantage of humidification was slight or questionable with cuttings of *Leucothoë*, *Stauntonia*, *Pterostyrax*, and *Thladiantha*. An adverse effect possibly may have been produced with *Corylus*. The benefits were beyond question with the other subjects and were outstanding with difficult clons of *Chionanthus*, *Chaenomeles* and *Ligustrum*.

Humidification was beneficial on cuttings of some other subjects of which sufficient numbers could not be obtained to permit a full series of trials in various locations with growth substance treatments at various levels of concentration. Cuttings of stems of *Rubus phoenicolasius* Maxim. and *R. ulmifolius* Schott were rooted about 60 per cent, although trials of these species had been near failures in previous seasons. An unidentified species of *Vitex* was rooted 60 per cent in 8 weeks under humidification, but was not rooted without it. Cuttings of *Castanea mollissima* Bl. and *Magnolia Sieboldii* K. Koch from greenhouse grown plants rooted well and greenwood cuttings of *Liriodendron Tulipifera* L. from outdoor trees produced some roots. Some response was obtained from the difficult subject *Corylus chinensis* Franch. and some unusually large cuttings of an unidentified variety of rhododendron taken on August 13 were starting to root by October 10. Results were poor with *Prunus Mahaleb* L., *P. maritima* Marsh. and X *Ceanothus pallidus* var. *roseus* (Carr.) Rehd. possibly because the cuttings were taken when the wood was not at the proper stage of development.

Cuttings of leguminous trees and shrubs are usually considered to be sensitive to excess moisture. Attempts to root outdoor-grown cuttings of honey locust under humidification were not successful, but greenwood cuttings forced from root cuttings or from potted trees cut back to stumps rooted perfectly under humidification. Apparently the condition of the cutting wood is a matter of greatest importance in determining the response to high humidity.

The beneficial effects on the rooting of cuttings produced by maintaining the air of a propagating greenhouse at a high degree of humidity are similar to those secured by using a spray which washes the foliage of the cuttings, provided the latter is not excessive. At the present time the advantages and disadvantages of the two alternative systems can hardly be compared fairly, since the optimal conditions have not been determined accurately for either method. Both systems must be considered as definite improvements in the technique of rooting greenwood cuttings in summer. However, the economy of operation, freedom from clogging, and the high efficiency of the centrifugal atomizer all combine to make this device particularly well suited for use with propagating equipment.

These investigations of propagating equipment were conducted through the cooperation of the Hillculture Division, Soil Conservation Service and the Division of Plant Exploration and Introduction, Bureau of Plant Industry, U. S. Department of Agriculture. Thanks are due to Mr. F. L. O'Rourke of the Hillculture Division for assistance. Dr. M. A. Raines, Howard University, made helpful suggestions regarding apparatus.

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The Use of Seed Characters in the Identification of Grape Varieties

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IN California grapes are grown commercially over a wider range of soil and climatic conditions than in any other viticultural country in the world. Here a variety can show a remarkable range of variation, depending on the imprint of the particular environment under which it is cultivated. Identification of a variety in the laboratory by study of a fruit sample of even a commonly grown variety may be difficult, especially since one cannot be fully acquainted with the variation met with in the particular locality from which the sample comes. This difficulty is most acute with the black varieties of wine grapes, of which a great number appear superficially alike and show overlapping variation of many characters.

Although one should make use of every descriptive feature that adequately distinguishes a variety, in the ordinary routine of identification the worker is usually limited to a small sample of the fruit, often one or two clusters. The author has been concerned with the identification of nearly a hundred samples each summer, and this fruit often arrives in such poor condition that identification is often impossible, or it cannot be kept in good condition until time permits its study. This has turned our attention to the study of the seeds. Varietal collections of seeds are easily made, may be kept indefinitely with the use of only a small cabinet or filing space, and may be conveniently studied or compared with known varieties at any time. A priori, one might expect the seed to be a less variable organ than many others ordinarily used in variety description, because of the cloistered environment in which it develops, shielded from the external environment by the thick berry flesh.

Seed characteristics that readily lend themselves to quantitative expression should be those of most interest to ampelographers. Many structures of the seed are of value for descriptive purposes and these have been best summarized by Bonnet (2) in France and later by Bioletti (1) in California, but purely descriptive words are subject to various interpretations, especially if they refer to varieties of international interest. Words in one language do not always convey the same meaning when translated to another. Casual mention has often been made of the fact that the mature seeds appear to have more constancy in development and mature form than other more widely used vegetative portions of the vine; however, no studies are known that attempt to establish this opinion. Krimbas (3) has used the ratio between the length of seed and length of berry as the most important adjunct in describing many varieties in Greece. Bonnet's work was principally with species of Vitis and he, like most authors, tended to minimize the importance of varietal differences.

Measurements that have low variability, both within a single sample and between samples from various localities over which the variety is grown, are best suited for descriptive work, providing they may also be easily obtained. Of these the measurements of seed weight, seed length, and seed width appear appropriate. Another measure used is the distribution of seeds in a berry sample, or again the mean number of seeds per berry. In this study we have used, as an indication of the variability of the material, the berry size, a character that is often used in the description of varieties. Similar data is available for berry number per cluster and cluster weight, but this shows the same high variability characterizing the berry weight and need not be included here.

MATERIAL AND METHODS

In order to compare several of the same varieties growing under diverse environmental conditions, collections of 10 primary clusters of each of three varieties were made at Glen Ellen and at Davis. Glen Ellen is quite typical of the North Coast dry-wine district, the climate is comparatively cool in summer, and the vines are grown without irrigation. The vines at the Glen Ellen vineyard were about 40 years old and grafted on Lenoir rootstock.

At Davis, in the hotter Sacramento Valley, the vines are irrigated, reach much greater size, and the yields are over three times as great as at Glen Ellen. The vines used at Davis were 7 years old and on their own roots. The difference in environmental conditions between the two localities is well expressed in the fruit — the Davis samples are larger sized clusters, with larger berries, of less color and softer texture than the Glen Ellen fruit. The berry weights are indicative of the variation in the fruit from each locality.

Random samples of 100 berries were taken from each of 10 clusters per variety from both locations. All of the seeds of the berry sample were extracted and dried for 2 days at room temperature. They were then weighed on an analytical balance to the nearest milligram, 1,000 seeds for each sample. A random sample of 200 seeds was used for length and width measurements, measuring the shadow obtained by microprojection, giving a 10× magnification at table level. Readings were made to the tenth of a millimeter.

Reference to Table I shows the berry weight of the Glen Ellen fruit to be consistently and significantly smaller than at Davis. Although in the Glen Ellen samples the varieties Carignane and Burger have the same size (weight) of berry, the Carignane has the larger berries at Davis. Whereas the Alicante Bouschet has the larger mean berry size in the Davis vineyard, this relationship is reversed in the case of the Glen Ellen fruit. The berry weights are not only found to be quite variable depending on locality, but likewise show a high coefficient of variation for a single sample, where $n = 1000$. It is apparent that the varieties cannot be easily differentiated even within the same locality on the basis of berry size. This same difficulty often arises in comparing varieties on the basis of other fruit characters, such as cluster size and berry number per cluster.

The mean weight of the seed ($n = 1000$) is more consistent and, despite the large increase in berry size, the average seed weight has not appreciably increased, except in the case of the variety Burger. The coefficient of variation is as high as in the berry weight determi-

TABLE I—SEED AND BERRY MEASUREMENTS OF THREE VARIETIES COLLECTED AT DAVIS AND GLEN ELLEN, CALIFORNIA

Variety	Berry Weight (Gms)		Seed Weight (Mgs)		Seed Length (Mm)		Seed Width (Mm)		Ratio $\frac{L}{W}$	
	Mean and Standard Error	C.V. Per Cent	Mean and Standard Error	C.V. Per Cent	Mean and Standard Error	C.V. Per Cent	Mean and Standard Error	C.V. Per Cent	Mean and Standard Error	C.V. Per Cent
					Davis					
Carignane..	2.3 ±.02	25.1	24.3 ±.25	32.3	6.5 ±.03	6.0	3.4 ±.02	7.7	1.86 ±.009	7.3
Alicante Bouschet	2.4 ±.02	29.4	20.8 ±.14	20.7	5.4 ±.02	6.3	3.1 ±.02	6.7	1.73 ±.007	5.6
Burger.....	2.2 ±.02	26.4	18.5 ±.17	29.5	6.1 ±.02	5.8	3.0 ±.02	8.5	2.05 ±.012	8.3
					Glen Ellen					
Carignane..	1.8 ±.02	27.1	24.5 ±.18	21.9	6.1 ±.08	5.9	3.4 ±.01	6.2	1.84 ±.010	7.5
Alicante Bouschet	1.7 ±.02	29.3	20.0 ±.18	28.2	5.3 ±.03	8.4	3.1 ±.02	8.8	1.75 ±.008	7.1
Burger.....	1.8 ±.01	20.8	15.6 ±.15	29.5	5.7 ±.02	5.6	3.0 ±.01	7.1	1.94 ±.010	7.4

nations. The mean seed weight is, however, influenced by the presence of hollow or "empty" seeds.

The seed length increases significantly for each variety in all samples with the increase in berry size. This response differs with the variety in question, as the Alicante Bouschet, a short and rather stubby seed, does not elongate nearly as much as do the Carignane and Burger seeds. The differences in seed length are rather marked between varieties, and the coefficient of variation is low. It appears that the seed length would be a good criterion of variety classification, at least it is well marked within a given locality. Unexpectedly, despite the increase of seed length with increase in berry size, the width of the seed is not significantly changed. The seed width would appear to be the best single quantitative measure of any seed character because of its constancy, but further study of additional varieties is necessary to determine if the range between varieties is large enough to justify its use alone. In employing the ratio $\frac{L}{W}$, the incorporation of both length and width would appear to have no great advantage over the expression of each measurement used singly.

The use of the $\frac{L}{W}$ ratio as being a better measure of seed size (Bonnet) becomes questionable if the data here has general application. It was proposed, a priori, that if changes in seed size occurred, the $\frac{L}{W}$ ratio would compensate for this, assuming the proportionate increase the same in both length and width. However, this is not the case, and it would appear that the measurements given singly have greater value.

There is only meager data in the literature that allows further

TABLE II—SEED MEASUREMENTS OF THE CARIGNANE

Year	Locality	Worker	Length (Mm)	Width (Mm)
1901	Montpellier, France	Bonnet	6.0	3.4
1938	Montpellier, France	Olmo	6.1	3.4
1935	Davis, California	Bioletti	6.4	3.7
1941	Davis, California	Olmo	6.5	3.4
1941	Glen Ellen, California	Olmo	6.1	3.4

comparisons of seed size in different seasons and localities. Table II summarizes the available figures for the Carignane.

It is interesting to note the closeness of the results obtained. Bioletti's figures on seed width are apparently not in conformity with the others reported, but the size of sample he used was too small and not taken at random, for he reports eliminating all small or misshapen seeds. The technique of seed sampling requires attention in some varieties where there are many small seeds that do not approximate even one-half normal size. Further work on this problem is now under way. Table I indicates the weight of the seed can also be used as a varietal characteristic, but the variability is much higher than length or width measurements. However. it is more rapid to weigh seeds than to measure them and it would be desirable that seed weight be included as a descriptive feature of varieties. For some varieties, such as Burger, the curve obtained for seed weights is bimodal owing to the presence of hollow seeds, those in which the endosperm does not fill the cavity.

The presence of hollow or "empty seeds" is a varietal characteristic, dependent entirely on the maternal parent, Olmo (4). Although wide fluctuations may occur from year to year and even between different regions in the same year, some varieties consistently produce a low proportion of hollow seeds, whereas others do not. Thus the Muscat of Alexandria produces about 7 per cent, whereas the Chaouch and Pearl of Csaba yield over 99 per cent of hollow seeds. Since the percentage of hollow seeds is easily determined by flotation in water, and for many varieties is sufficiently constant, it should be added to those other seed measurements that have value in variety description.

Other morphological characters of the seed of value that have not been considered by previous workers (1, 2) and do not lend themselves to quantitative measurement might be mentioned. The color of the beak may be quite useful in variety identification, especially in freshly extracted seed. In California, fruit of the Feher Szagos may be distinguished from similar varieties by the striking white-tipped beak. In many varieties there are black or brown colorations on the beak that appear constantly and should be noted.

In some varieties there is a shallow linear depression that extends from the chalaza to the beak, and this may be absent altogether, or quite pronounced. This can be conveniently referred to as the dorsal groove.

SUMMARY

The seeds of the grape are useful in variety identification, since they are easily obtained, and, unlike the fruit itself, they may be filed in a

permanent collection and studied or compared at any convenient time.

The mature seed, as judged by weight, length, and width measurements, is far more constant than other fruit characters commonly used in variety description, such as berry size, number of berries per cluster, and cluster weight.

Although the seed length may increase appreciably with increase in berry size, the width remains practically constant under the two environmental conditions studied. The value of using a ratio of $\frac{L}{W}$ is therefore not warranted, since the original premise (2) is not fulfilled, namely, that if environmental conditions were favorable and the seed were to enlarge, the increase of the two axes would be proportional.

Morphological features of the seed of value in descriptive work, and not mentioned or used by previous workers, are described.

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The Performance of Champanel Grapes Under Different Pruning Treatments

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THE Champanel grape is one of the most vigorous and longest-lived varieties of grape grown in the South; also it is fairly resistant to disease and will withstand a certain amount of poor treatment. These qualities make it a valuable variety to growers despite its mediocre quality as a table grape.

It does have the fault of yielding poorly when cane-pruned, and of producing poorly filled fruit clusters. Yet the vines are excessively vegetative, often yielding 12 to 15 pounds of prunings per vine in a closely planted vineyard. The flowers are fully fertile, producing an abundance of viable pollen. In work carried on at this Station increasing the number of buds on cane-pruned vines failed to give an appreciable increase in yield of fruit. The buds on cane-pruned vines practically all started growth, but the apical buds outgrew the others so that the growth was short and weak and usually dead at the end of the growing season. This growth failed to produce much fruit and practically no marketable clusters. Pinching off the new growth once during the season just beyond the last blossom cluster at or just before blossoming time failed to alter appreciably the growth type from any of the nodes on the cane. Since the variety exhibits very strong apical bud dominance, it was thought that spur pruning that would increase the number of terminals might give a proportionate increase in the number of new shoots and also increase the yield.

Cultural practices are known which sometimes increase the production, and set of fruit. Bioletti and Flossfeder (2), working in California, found that on some varieties of vinifera grapes and under certain conditions, pruning back or pinching back the new growth at or just before blossom time was effective in increasing the set of fruit,[1] and certain vinifera varieties require annual ringing or girdling of the vines for the production of a successful crop (3). If the girdling is done while the vines are in bloom, the number of berries per cluster of certain seedless varieties is increased (4).

An experiment on 10 own-rooted Champanel vines was initiated at Meridian, Mississippi, in 1940 to test these practices. The vines had been planted in 1934 and were set 8 by 10 feet apart. Five vines were spur-pruned and five vines were cane-pruned during both 1940 and 1941. During 1940 some pinching back of young growth just above the last blossom cluster was done at blossoming time on certain vines. At harvest time individual fruit cluster weights were obtained on all the experimental vines. In 1941, all of the new canes on two of the spur-pruned vines were pinched back and the remaining three were left unpinched. One of the unpinched vines was girdled at approximately the same time that the pinching was done in an effort to increase the set of fruit. The same treatments were applied to the five cane-pruned vines. Where a portion of a vine was treated in 1940, it was thought that the treatment might tend to affect the remainder of the vine or that the untreated portions might exert an influence on the treated portions. For this reason entire vines were used in the 1941 experimental treatments. Cultivation, fertilization, spraying, and time of pruning were uniform for all experimental vines. The results were measured by the yield per vine and the weight per cluster, both in pounds. In 1940, a count of the number of berries per cluster was made. This number was found to be highly correlated with the weight of the clusters. There was no significant difference between the fruit cluster weight from the girdled, and from the ungirdled vines, and these data were included with those of the other unpinched vines.

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[1] Mr. Carl Schuessler, a practical vineyardist of La Fayette, Alabama, stated that this treatment was effective in increasing the set of Champanel fruit.

The data for the two years are summarized in Tables I and II.

TABLE I—EFFECT OF SPUR PRUNING VERSUS CANE PRUNING ON YIELD AND FRUIT CLUSTER WEIGHT OF OWN-ROOTED CHAMPANEL GRAPE VINES GROWN AT MERIDIAN, MISSISSIPPI

Pruning Treatment	Average Yield Per Vine (Pounds)	Average Difference in Yield Due to Spur Pruning* (Pounds)	Average Cluster Weight (Pounds)	Average Difference in Fruit Cluster Weight Due to Spur Pruning (Pounds)
		1940		
Spur	12.24 ±2 3**	——	.196 ±.0136	——
Cane	5.90 ± .9	+ 6.34†	.178 ±.0116	+.018
		1941		
Spur	24.30 ±2.8	——	.204 ±.015	——
Cane	10.21 ±2.9	+ 14.09‡	.214 ±.034	-.010

*Data analyzed by Snedecor's method of group comparisons (*6*).

**Standard error

†Significant at 5 per cent level.

‡Significant at 1 per cent level.

TABLE II—EFFECT OF PINCHING THE YOUNG GROWTH JUST ABOVE THE LAST BLOSSOM CLUSTER AT BLOSSOMING TIME ON THE WEIGHT OF FRUIT CLUSTER AND YIELD OF OWN-ROOTED CHAMPANEL GRAPE VINES GROWN AT MERIDIAN, MISSISSIPPI

Pinching Treatment	Average Weight of Fruit Cluster (Pounds)	Average Difference in Weight of Fruit Cluster Due to Pinching* (Pounds)	Average Vine Yield (Pounds)	Average Difference in Yield Due to Pinching (Pounds)
		1940		
Pinched	.243 ± 024**	——	†	——
Not pinched	.169 ±.006	+.074‡	——	——
		1941		
Pinched	.265 ±.019	——	21.33 ±5.7	——
Not pinched	.172 ±.009	+.093‡	14.54 ±3.3	+6.79

*Data analyzed by Snedecor's method of group comparisons (6).

**Standard error.

†Data omitted since some vines had both treatments.

‡Significant at 1 per cent level.

DISCUSSION

These results showing increased yields from spur pruning of the Champanel grape as compared with cane pruning are not in agreement with the findings of Maney (5), who worked with the Concord variety, or with those of many others who have noted the performance of varieties similar in growth habits to the Concord. The Concord variety, however, does not show the strong tendency to growth dominance of the apical buds exhibited by the Champanel, and the present findings are not considered to be in conflict with the observations of these other workers with other varieties. The value of the spur pruning method would doubtless apply only to those varieties showing strong growth dominance of the apical buds.

With respect to the matter of pinching versus nonpinching of canes, other workers (1, 2) have held that pinching or topping is devitalizing to the vine and ordinarily is of questionable value except on excessively vigorous vines. It is recognized that the practice may be overdone, particularly with weak vines, and repeated pinching throughout the growing season may have a detrimental effect where the whole vine is involved in the process. Pinching as practiced in the present case with the Champanel variety did favor a better set of fruit within the cluster and no detrimental effects were noted. It tended to increase yield per vine, but not significantly in this study.

SUMMARY

This test shows that the yields of own-rooted Champanel grape vines grown at Meridian, Mississippi, were significantly increased by spur pruning over those obtained by cane pruning; also that the weight of the clusters was significantly increased by pinching off the new growth just beyond the last blossom cluster at the time of blossoming. The results did not show a significant difference in yield between pinching versus no pinching treatments as measured by vine yields, nor a significant difference between spur pruning versus cane pruning treatments as measured by fruit cluster weights.

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Maturity Studies with California Grapes II. The Titratable Acidity, pH, and Organic Acid Content[1]

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IN THE previous report (2) the utility of the empirical ratio of Balling (soluble solids) to the titratable acidity of the musts as a means of evaluating wine-grape varieties for wine-making purposes was considered. The present paper deals with the changes in titratable acidity, pH, and the organic acids during maturation and also considers some of the applications of this data to the appraisal of varieties of wine grapes for wine production.

The important acids found in grape musts are tartaric, malic, tannic, phosphoric and citric, the first two constituting well over 90 per cent of the total. Small amounts of sulfurous and sulfuric acids are found in musts treated with sulfur dioxide. All of these, and other acids as well, are found in wines. The acids are chiefly important because of the acid taste which they give to the wine. But this effect, at least partially, and other effects wholly, depend on the hydrogen ion concentration rather than the concentration of acids *per se* (22).

As early as 1906 Paul and Gunther (23) measured the hydrogen ion concentration of wines and numerous later works have established the limits of the pH in European wines and musts [see especially Genevois and Ribéreau-Gayon (11)]. The lack of any well-defined correlation between the pH and titratable acidity was noted by Paul (20, 21) and later by Brémond (5) and Pato (19).

Crisci (6) in Italy, von der Heide (29) in Germany, Seifert (25) in Austria, Brémond (5) in Algeria, Gerassimoff (12) in the Crimea, and many others have published data on the pH of musts and wines. Gerassimoff's data is particularly interesting in that it covers a large number of varieties.

The importance of pH in establishing the percentage of free acid was early recognized by von der Heide and Baragiola (28) who found over 30 per cent of the tartaric acid and over 50 per cent of the malic acid to be free in two German wines. Tarantola (26) found a somewhat lower percentage of the tartaric to be free in an Italian wine. Peynaud (24) has also found a large percentage of free acid in two Bordeaux musts.

The high pH Muscat wines of northern Italy have been noted by Tarantola (26) to give poor hydrolysis of sucrose when they are used for making sparkling wines if the sugar is not hydrolyzed prior to bottling.

The extraction of coloring matter and probably of flavoring constituents are better at the lower pH. The color of the resulting wines is also more stable and of a better tint under such conditions [see

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[1] We are indebted to Mr. William Dietrich and Mr. A. Dinsmoor Webb for conducting most of the analysis, as well as for suggestions regarding the analysis of the data.

Winkler and Amerine (31)]. The changes in pH during ripening have not been studied so extensively. Crisci (7), however, has followed the changes in titratable acidity and pH in two varieties during ripening and has found a continuous decrease in acidity and rise in pH during the later stages of maturation. The curves of Amerine and Joslyn (1) also show this and likewise show the small rise in acidity and decrease in pH which takes place very early in the season. This early rise in acidity was also noted by Bioletti, Cruess, and Davi (4). Gerassimoff's data (12) from August to October shows a regular increase in pH.

The alcoholic fermentation of musts of relatively low pH by a mixed culture of yeasts and bacteria, which is always the case in commercial practice, is very satisfactory, since such a condition is more unfavorable to the bacteria than to the yeasts [see especially Ventre (27)]. The fermentation of musts of high pH (above 4.0) is always hazardous, particularly when the fermentation is to be carried to complete dryness, and the resulting wines are usually of poor keeping quality. In the preparation of sweet fortified wines a relatively high pH is not objectionable.

Many studies on the changes in titratable acidity during maturation have been made, that of Girard and Lindet (13) being one of the earliest and classical. [See also Bioletti, Cruess and Davi (4) and Mach (18)]. But these studies, since they are divorced from simultaneous determination of the organic acid fractions and of the pH, yield little information concerning the acid balance of the grapes.

Genevois (10) has reviewed the literature on the changes in organic acids during maturation. The ratio of tartaric acid to total acids, the coefficient of maturation of Ferré (8, 9), is found to be higher for the better quality varieties and during the best seasons. Peynaud (24) has also found differences in the relative amount of tartaric and malic acids in various wine-grape varieties; high tartaric compared to malic being associated with the Merlot, Sémillon, and Sauvignon blanc, while in the Malbec and Cabernet franc only about two times as much tartaric as malic was present at maturity.

The percentage of malic acid present is important, since it is readily utilized by certain bacteria. In the case of overly acidic wines this fact is utilized, since the biological degradation of malic acid is a practical means of makng such wines palatable (9, 11). Wines with excessive tartaric acid are also objectionable because they have a low pH and a green, acidulous taste. This condition is less amenable to correction.

PROCEDURES AND CALCULATIONS

Duplicate random samples of portions of the clusters, averaging about 600 grams each, were collected periodically during the season, July to October. The juice was separated from the stems, skins, and pulp by a continuous type of laboratory press. The supernatant juice was immediately centrifuged, 5 minutes at 3,000 revolutions per minute, and the clear material used for the subsequent determinations.

To 20 milliliters of this clear juice in a 50-milliliter beaker, the following were added: 3 grams of pulverized potassium chloride, 0.5 milliliter each of glacial acetic acid and 20 per cent potassium acetate, and 6 milliliters of 96 per cent ethyl alcohol. The mixture was brought to a boil to dissolve the potassium chloride and to coagulate some of the colloidal material of the musts. The beaker was then placed at 32 degrees F for at least 12 hours. The material was filtered through fine filter paper in a Gooch crucible and the precipitate washed with less than 20 milliliters of a mixture of 15 grams of potassium chloride and 20 milliliters of 96 per cent ethyl alcohol in 100 milliliters of water. The malic acid is in the filtrate while the tartrates are in the precipitate on the filter paper.

The tartrates were determined by dissolving them off the filter paper with boiling alkali-free water and titrating the filtrate at once with alkali to a phenolphthalein end point. Since potassium acid tartrate is somewhat soluble, a correction must be made. Using von der Heide's (29) formula and calculating for 20 milliliters of must and 0.0336 *N* alkali, the grams of tartaric acid per 100 milliliters of must is 0.252 (a + 0.893) where "a" is the milliliters of alkali used in the titration.

The filtrate containing the malates was evaporated to about 10 milliliters and the malic acid determined by a modification of Peynaud's (24) procedure. The reduced filtrate was neutralized with ammonium hydroxide (1 + 2), and 5 milliliters of *N* barium chloride and 3 milliliters of 33 per cent barium acetate added. Sixty milliliters of 96 per cent ethyl alcohol which had been previously saturated with barium malate were added so that the final concentration of alcohol is over 88 per cent as recommended by Auerbach and Krüger (3). The mixture was placed at 32 degrees F overnight to allow the barium malate to precipitate.

The solution was filtered on a small Büchner funnel using No. 40 Whatman paper. The precipitate was washed with 25 milliliters of 72 per cent ethyl alcohol. This had likewise been saturated with barium malate. The precipitate was then washed into a 100 milliliter volumetric flask using hot water, 5 milliliters of *N* sulfuric acid were added to precipitate the excess barium, the solution cooled and brought to 100 milliliters. Ten to 20 milliliters of the clear supernatant liquid were used for the malic acid determinations.

An all-glass distillation apparatus was arranged so that very dilute, 0.01 *N* to 0.005 *N*, permanganate could be introduced drop by drop just above the surface of the boiling liquid. The solution was buffered to a pH of 3.2 with 10 to 20 milliliters of a phosphate buffer (prepared from 150 grams of potassium dihydrogen phosphate and 5 milliliters of phosphoric acid made up to a liter with water). One milliliter of a solution of manganous sulfate (50 grams per liter of water) was added to catalize the reaction. Pieces of capillary tubing placed in the distillation flask were effective in preventing bumping. The volume of solution in the boiling flask was kept as constant as possible. The boiling should be very vigorous. Between 10 and 15 milliliters were distilled to remove traces of alcohol and air before introducing any permanganate. Under these conditions malic acid is oxidized to acetaldehyde:

$$COOH - CH_2 - CHOH - COOH + \frac{1}{2} O_2 = CH_3CHO + 2CO_2 + H_2O$$

The acetaldehyde produced is received in a buffered solution of bisulfite and determined according to the procedure of Jaulmes and Espezel (14) as modified by Joslyn and Comar (16).

The pH of the must was determined on a separate aliquot of juice with a Beckman pH meter and the titratable acidity on another aliquot by titration with 0.1 *N* of sodium hydroxide to a phenolphthalein end point. Occasionally the titrations were checked by titrating potentiometrically to a pH of 7.7 or by titration to a phenol red end point. During most of the season there is a very small, albeit constant, difference between the titrations to a phenol red as compared to a phenolphthalein end point.

From the above determinations the pH, the total titratable hydrogen, total tartrate, and total malate of the grape juice are known. It is possible to calculate from this data the amount of free malic and tartaric acids, of potassium acid malate and tartrate, and of potassium malate and tartrate present, using the formulae

$$\mathrm{pH} = \mathrm{pKa}_1 + \log \frac{\text{acid salt}}{\text{acid}} \text{ and} \qquad (1)$$

$$\mathrm{pH} = \mathrm{pKa}_2 + \log \frac{\text{salt}}{\text{acid salt}}. \qquad (2)$$

Various values for the pKa's of malic and tartaric acids have been published. The best late data for tartaric acid is that of Jones and Soper (15) giving a pKa_1 of 2.98 and pKa_2 of 4.34. The International Critical Tables' (30) value of 3.41 for the pKa_1 and the Landolt-Börstein (17) value of 5.14 for the pKa_2 for malic acid have been used. For a must having a pH of 3.57 equation 1 becomes for tartaric acid and potassium acid tartrate

$$3.57 = 2.98 + \log \frac{\text{acid salt}}{\text{acid}} \text{ and}$$

$$\frac{\text{acid salt}}{\text{acid}} = 3.9 \qquad (3)$$

Likewise for potassium acid tartrate and potassium tartrate equation 2 becomes

$$3.57 = 4.34 + \log \frac{\text{salt}}{\text{acid salt}} \text{ and}$$

$$\frac{\text{salt}}{\text{acid salt}} = 0.162$$

By direct determination in this must the total tartrate present, calculated as tartaric acid, was found to be 0.668 so that

$$\mathrm{H_2Ta} + \mathrm{KHTa} + \mathrm{K_2Ta} = 0.668 \qquad (4)$$

Substituting

$$H_2Ta + 3.9\,H_2Ta + (3.9)(0.162)H_2Ta = 0.668 \text{ or}$$
$$H_2Ta = 0.121$$

Substituting this value in 3 above gives the amount of acid salt. And substituting the value for acid and acid salt in equation 4 gives the amount of potassium tartrate. The percentages of tartaric acid, acid tartrate, and tartrate in this must (calculated as tartaric acid) were therefore 0.121, 0.471, and 0.076 respectively.

In a similar fashion the malic acid, acid malate, and malate present can be calculated from the total amount of malic acid found and by using the proper constants and equations given above. It is understood, of course, that these equations are not exact, since no correction for the activity of the ions involved has been made, but at the concentrations involved the error is insignificant.

The number of milliliters of 0.1 *N* sodium hydroxide required to neutralize 100 milliliters of grape juice is known. The milliliters required to neutralize the four acid substances differentiated above can be calculated, since the milliliters of 0.1 *N* alkali necessary equal 10 times the grams present divided by the milliequivalent weight. In the example above for tartaric acid: $\frac{10 \times 0.136}{0.150} = 35.5$ milliliters; for malic acid: $\frac{10 \times 0.52}{0.134} = 7.8$ milliliters; for potassium acid tartrate: $\frac{10 \times 0.449}{0.075} = 16.7$ milliliters; and for potassium acid malate: $\frac{10 \times 0.071}{0.067} = 5.3$ milliliters.

In this case 100 milliliters of the original juice required 70.0 milliliters of 0.1 *N* alkali and the summation given accounts for 65.3 milliliters. It may be concluded that this recovery was very good considering the procedures used for determining tartaric and malic acids in musts. Some loss of tartaric acid occurs when the tartrate precipitate is difficult to filter. Musts high in colloidal material are sometimes very difficult to filter.

PRESENTATION OF DATA

The pH values for 75 grape varieties collected from the warm, moderate, and cool regions of California are shown in Table I. The range in pH of California musts is not only larger than that reported for any other single country but the average value is appreciably higher than that of most.

About 85 per cent of the musts have pH's from 3.11 to 3.80 with the largest number falling into the class 3.41 to 3.50.

TABLE I—RANGE IN PH IN CALIFORNIA MUSTS AND THE CORRESPONDING WINES FOR THE SEASONS 1939, 1940, 1941

pH	Musts					Wines			
	1939	1940	1941	Total	Average (Per Cent)	1939	1940	Total	Average (Per Cent)
2.71–2.80	—	—	1	1	0.08	1	—	1	0.12
2.81–2.90	7	1	2	10	0.84	7	—	7	0.81
2.91–3.00	21	4	11	36	3.01	7	—	7	0.81
3.01–3.10	38	11	25	74	6.19	8	5	13	1.50
3.11–3.20	57	34	36	127	10.62	23+(1)*	11	35	4.03
3.21–3.30	62	52	39	153	12.80	42	27+(1)	70	8.07
3.31–3.40	60	64	38	162	13.54	41+(1)	25+(2)	69	7.96
3.41–3.50	54	76	52	182	15.22	48+(2)	39+(1)	90	10.39
3.51–3.60	45	71	36	152	12.71	34+(1)	53+(5)	93	10.72
3.61–3.70	35	50	26	111	9.28	33+(6)	30+(9)	78	9.00
3.71–3.80	19	71	15	105	8.78	24+(2)	40+(13)	79	9.11
3.81–3.90	17	21	6	44	3.68	24+(11)	45+(10)	91	10.50
3.91–4.00	8	9	6	23	1.92	18+(21)	25+(17)	81	9.34
4.01–4.10	—	10	1	11	0.92	13+(17)	11+(18)	69	7.96
4.11–4.20	1	2	2	5	0.42	4+(9)	6+(21)	40	4.62
4.21–4.30	—	—	—	—	—	1+(11)	3+(12)	27	3.11
4.31–4.40	—	—	—	—	—	0+(3)	0+(4)	7	0.81
4.41–4.50	—	—	—	—	—	0+(4)	0+(2)	6	0.69
4.51–4.60	—	—	—	—	—	0+(4)	—	4	0.46

*Figures in parenthesis are for wines that have been fortified to 20.0 per cent alcohol with fortifying brandy.

The pH of the wines is greatly influenced by the addition of alcohol during fermentation; the pH being markedly increased. This apparently arises from the increased precipitation of acid tartrate in high alcohol (20 per cent) solutions, from the dilution by the alcohol, as well as from the direct influence of the higher alcohol content on the activity of the hydrogen ions. Otherwise the distribution of pH's in the wines is relatively the same as in the must.

In Table II a season's summary of a maturity study on a single variety of grape is given. The last column is the per cent of the actual titration which is accounted for by the tartaric and malic acids and acid tartrate and malate which were determined. To improve the per cent recovery, larger samples should be taken and more duplicate analyses made. Even so, an occasional sample, such as that of August 20th, is out of line and fails to give a normal recovery. The citric and phosphoric acid content (24) is very small, hence its inclusion in the determinations would only raise the per cent recovery slightly.

In Table III are summarized the data on the amount of total tartrates and malates present (calculated as tartaric and malic acid respectively) during the ripening period and the per cent of the total titratable acids which are accounted for by the tartaric acid and potassium acid tartrate for several varieties of grapes.

In all cases there is a steady decrease in the per cent of tartrates and malates, but the per cent of the total titratable acids which are due to the tartaric acid and potassium acid tartrate increases. Early in the season the differences in the percentage of total tartrate plus malate between varieties are small. Barbera, Sylvaner, Carignane, and Valdepenas have a relatively high percentage and Chasselas doré, Flame Tokay, Mission, Muscat of Alexandria, Ohanez, Ribier, and Sultanina are somewhat lower.

There is a marked difference, however, in the per cent of the total

TABLE II—THE CHANGES IN THE MUST OF VALDEPENAS PICKED AT TWO-WEEK INTERVALS IN DAVIS FOR THE SEASON OF 1941

Date	Average Berry Weight (Gms)	Ball-ing	Titratable Acidity, Cc 0.1 N Per 100 Cc	pH	H_2Ta	KHTa	K_2Ta	H_2Ma	KHMa	K_2Ma	Cc 0.1 N OH^- Equal to H_2Ta + KHTa	Cc 0.1 N OH^- Equal to H_2Ma + KHMa	Cc 0.1 N OH^- Equal to H_2Ta + KHTa + H_2Ma + KHMa	Per Cent Titrat-able tartrates	Per Cent Actual Titra-tion
Jul 9...	0.701	6.25	393.0	2.71	0.855	0.458	0.011	1.449	0.289	0.001	144.5	237.6	382.1	37.8	97.3
Jul 23..	0.919	10.15	392.5	2.74	0.749	0.426	0.011	1.488	0.314	0.001	128.2	245.5	373.7	34.4	95.1
Aug 6..	1.271	15.70	239.5	2.91	0.433	0.369	0.014	0.885	0.280	0.002	82.3	153.0	235.3	35.0	98.2
Aug 20.	1.714	20.90	115.0	3.32	0.170	0.389	0.039	0.210	0.170	0.003	48.5	44.1	92.6	52.3	80.6
Sep 3...	1.750	22.15	101.6	3.30	0.185	0.383	0.034	0.235	0.182	0.003	50.2	48.7	98.9	50.8	97.4
Sep 17..	1.705	23.90	84.0	3.40	0.149	0.391	0.045	0.143	0.140	0.002	45.9	31.7	77.6	59.1	92.4
Oct 1...	1.650	25.85	87.7	3.51	0.127	0.431	0.064	0.135	0.169	0.004	45.6	32.8	78.4	58.2	89.4

TABLE III—PER CENT TOTAL TARTRATE AND MALATE AND PER CENT OF TOTAL TITRATABLE TARTRATE PLUS TITRATABLE MALATE DUE TO ACID TARTRATE AND TARTARIC ACID

Year	5 to 10 Degrees Balling			10 to 15 Degrees Balling			15 to 20 Degrees Balling			20 to 25 Degrees Balling			25 to 30 Degrees Balling		
	Total Tartrate	Total Malate	Acidity Due to Tartrates	Total Tartrate	Total Malate	Acidity Due to Tartrates	Total Tartrate	Total Malate	Acidity Due to Tartrates	Total Tartrate	Total Malate	Acidity Due to Tartrates	Total Tartrate	Total Malate	Acidity Due to Tartrates
Barbera															
1941	1.585	2.011	39.4	1.349	1.923	36.7	1.120	0.976	47.7	1.075	0.568	58.8	0.717	0.356	60.3
Carignane															
1939	1.125	2.089	30.5	0.893	1.219	36.1	0.880	0.641	44.8	0.411	0.323	48.3	—	—	
1940	—	—	—	1.049	1.540	35.2	0.855	0.843	43.4	0.708	0.432	53.1	0.936	0.346	59.2
1941	1.325	2.026	34.5	0.859	1.542	32.7	0.782	0.603	49.1	0.606	0.473	48.3	0.418	0.417	46.4
Chasselas doré															
1939	—	1.215	—	—	0.788	—	0.551	0.267	60.2	0.523	0.187	65.4	—	—	—
Flame Tokay															
1939	—	—	—	0.720	1.243	30.7	0.508	0.543	41.3	0.433	0.323	56.1	—	—	—
1940	—	—	—	0.689	0.888	34.7	0.493	0.352	50.1	0.494	0.263	55.2	—	—	—
Mission															
1940	—	—	—	0.929	1.316	35.9	0.717	0.660	42.7	0.493	0.323	50.1	0.567	0.252	58.6
1941	1.104	1.874	31.9	0.754	0.796	39.5	0.615	0.416	51.8	0.611	0.474	48.9	0.554	0.271	58.6
Muscat of Alexandria															
1940	1.064	2.539	24.9	—	—	—	0.667	0.509	48.6	0.575	0.292	57.5	—	—	—
1941	1.069	1.758	33.6	0.688	0.626	45.3	0.537	0.250	61.5	0.495	0.172	67.3	0.493*	0.151*	69.1*
Ohanes															
1939	0.758	1.579	27.6	0.518	0.562	40.6	0.511	0.400	48.1	0.460**	0.265**	54.9**	—	—	—
1940	0.989	1.884	29.7	0.754	1.048	35.6	0.586	0.385	51.8	0.535***	0.187***	51.7***	—	—	—
1941	0.925	1.788	29.2	0.655	0.876	37.6	0.552	0.340	53.7	0.493†	0.287†	54.0†	—	—	—
Ribier															
1939	—	2.035	—	0.573	0.579	42.8	0.419	0.300	51.7	0.368‡	0.260‡	55.1‡	—	—	—
1940	0.735	1.662	26.2	0.556	0.867	31.1	0.391	0.431	38.5	0.391	0.319	44.3	—	—	—
1941	0.987	1.931	29.4	0.664	0.890	38.5	0.460	0.557	46.0	—	—	—	—	—	—
Sultanina															
1939	—	—	—	0.823	0.659	49.4	0.679	0.319	62.2	0.637	0.145	77.1	0.466	0.083	81.1
1940	—	—	—	—	—	—	0.802	0.497	56.5	0.716	0.179	74.3	0.697	0.121	80.3
1941	1.953	2.100	42.8	1.590	2.069	38.8	0.947	0.657	53.3	0.773	0.231	71.4	0.673§	0.125§	79.0§
Sylvaner															
1940	—	—	—	0.866	1.160	37.4	0.734	0.561	49.0	0.624	0.447	48.7	—	—	—
1941	1.183	2.035	31.8	0.919	1.757	32.3	0.812	0.536	52.1	0.679	0.554	49.4	0.609	0.355	59.1
Valdepenas															
1940	—	—	—	—	—	—	0.661	0.705	40.9	0.595	0.353	53.2	0.551	0.172	68.2
1941	1.324	1.739	37.8	1.186	1.803	34.4	0.816	1.167	35.0	0.595	0.363	54.1	0.622	0.308	58.2

*Last of three samples over 20; Balling 24.0.
**Last of two samples over 15 Balling; Balling 16.0.
***Last two of four samples over 15 Balling; Balling 18.0.
†Last of four samples over 15 Balling; Balling 17.8.
‡Last of three samples; Balling 19.2.
§Last of four samples over 20; Balling 24.0.

TABLE IV—pH AND PER CENT OF TOTAL TARTRATES AND MALATES PRESENT AS FREE ACID AT VARIOUS BALLINGS

Year	5 to 10 Degrees Balling			10 to 15 Degrees Balling			15 to 20 Degrees Balling			20 to 25 Degrees Balling			25 to 30 Degrees Balling		
	pH	Tartrates Present as Free Acid	Malates Present as Free Acid	pH	Tartrates Present as Free Acid	Malates Present as Free Acid	pH	Tartrates Present as Free Acid	Malates Present as Free Acid	pH	Tartrates Present as Free Acid	Malates Present as Free Acid	pH	Tartrates Present as Free Acid	Malates Present as Free Acid
Barbera															
1941	2.49	75	89	2.49	75	89	2.81	59	81	3.02	47	71	3.02	47	71
Carignane															
1939	2.58	71	86	2.88	54	77	3.05	46	70	3.53	21	44	—	—	—
1940	—	—	—	2.76	62	82	3.00	48	72	3.47	23	47	3.55	19	41
1941	2.62	69	86	2.87	56	78	3.08	43	68	3.26	33	59	3.51	20	44
Chasselas doré															
1939	—	—	—	2.90	—	77	3.54	20	—	—	—	—	—	—	—
Flame Tokay															
1939	—	—	—	2.91	53	76	3.23	35	61	3.58	18	36	—	—	—
1940	—	—	—	3.09	42	68	3.46	24	48	3.79	11	29	—	—	—
Mission															
1940	—	—	—	2.82	58	78	3.20	36	62	3.60	17	41	3.86	9	25
1941	2.70	65	84	3.12	41	66	3.21	36	61	3.36	27	55	—	—	—
Muscat of Alexandria															
1940	2.74	63	82	—	—	—	3.29	32	59	3.57	18	40	—	—	—
1941	2.53	74	89	3.05	46	70	3.09	42	68	3.36	27	53	3.50*	21*	44*
Ohanez															
1939	2.94	51	77	3.10	42	67	3.23	35	61	3.43**	24**	48**	—	—	—
1940	2.71	65	83	3.07	44	69	3.42	25	49	3.48†	22†	45†	—	—	—
1941	2.73	64	82	2.99	49	74	3.43	24	48	3.49‡	22‡	45‡	—	—	—
Ribier															
1939	2.73	—	82	3.06	45	69	3.56	21	42	—	—	—	—	—	—
1940	2.70	65	84	3.17	39	65	3.54	20	43	3.78	11	30	—	—	—
1941	2.59	71	87	2.93	53	77	3.50	21	44	—	—	—	—	—	—
Sultanina															
1939	—	—	—	2.85	56	78	3.04	46	70	3.27	33	61	—	—	—
1940	—	—	—	—	—	—	3.01	47	73	3.38	27	52	3.55	19	41
1941	2.32	82	92	2.51	74	89	2.76	62	82	3.13	41	66	3.41§	24§	50§
Sylvaner															
1940	—	—	—	2.71	65	83	3.16	38	64	3.60	17	41	—	—	—
1941	2.71	65	83	2.97	49	75	3.24	33	59	3.32	31	55	3.67	15	35
Valdepenas															
1940	—	—	—	—	—	—	3.21	36	61	3.67	15	35	3.68	14	34
1941	2.71	65	83	2.74	63	82	2.91	53	76	3.34	28	54	3.51	20	44

*Last of three samples; Balling 24.8.
**Last of two samples; Balling 16.0.
†Last two of four samples; Balling 18.1.
‡Last of three samples; Balling 19.2.
§Last of four samples; Balling 24.0.

Note: The percentage figures in this table are derived from experimental data and not from calculations based on pH.

titratable acidity which is due to tartaric acid and potassium acid tartrate compared to malic acid and acid malate. Varieties with a percentage below 50 per cent at 20 to 25 Balling include Carignane, Mission, Ribier (possibly), and Sylvaner. Varieties with 50 to 65 per cent were Barbera, Chasselas doré, Flame Tokay, Muscat of Alexandria, Ohanez, and Valdepenas. The Sultanina was very low in malic acid and acid malate, the per cent of the total titratable acidity due to tartaric acid and acid tartrate being about 75, reaching 80 at Ballings exceeding 25. Varieties with a high percentage of tartrates compared to malates might generally be expected to have lower pH's if they also have equal percentages of tartrate present. Varieties such as Flame Tokay and Ribier have a low tartaric acid content although over 50 per cent of the total titratable acid is derived from the tartaric acid and acid tartrates.

The steady increase in pH during maturation reflects the continuous change in the ratio of acid salts to free acid. The data in Table IV shows the changes in per cent of total tartrates and malates which are present as free acids during maturation. Whereas early in the season some 50 to 80 per cent of the tartrates are present as free acid, these amounts are reduced to 10 to 20 per cent by the time the fruit is mature, (except for the Barbera, which is a typical high-acid, low pH variety).

SUMMARY

The principal acids of the vinifera grapes are tartaric, malic, tanic, phosphoric and citric. The tartaric and malic constitute well over 90 per cent of the total.

Methods for the separation and determination of the tartaric and malic acids and their salts in grape musts and the procedures employed in the calculations are indicated.

The pH of grapes grown in the present producing areas of California is higher than that of most grape-growing countries. The range too is very great. Generally speaking, the pH of a wine is relatively the same as that of the must, except in fortified wines, where it is markedly increased.

While there is a regular decrease in the tartrates and malates during ripening, the per cent of the total titratable acids which are owing to the tartaric acid and the potassium acid tartrate increases. In the immature fruit there is little difference between varieties in the percentage of the titratable acidity which is due to the tartaric acid plus acid tartrate compared to malic acid plus acid malate; however, as the fruit matures, there is a marked difference in the per cent of the total titratable acidity which is due to tartaric acid and potassium acid tartrate. Varieties may readily be grouped on the basis of this difference.

The steady rise in the pH during ripening reflects the change in the ratio of acid salts to free acid. In the green fruit, from 50 to 80 per cent of the tartrates are present as free acid while at maturity only 10 to 20 per cent are in this form. The varieties show a marked difference in free acid. Of those included in this investigation, the Ohanez and Flame Tokay possess relatively smaller amounts of free acid

throughout the season, while the Barbera and Sultanina have a relatively high amount.

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Some Effects of Zinc Sulphate on the Alexandria Grape

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SOME effects of zinc sulphate on the Alexandria (Muscat of Alexandria) grape have been under observation during the past three years at the United States Horticultural Field Station, Fresno, California. The results of the treatments with zinc sulphate are reported here. The Alexandria grape, an important vinifera variety, has produced extremely loose clusters in the station vineyard, and it has been very variable in fruit setting in many commercial vineyards. It has been shown by Chandler and others (1) that a zinc sulphate solution brushed on the fresh pruning cuts of vinifera grape vines very badly affected with little-leaf gave beneficial results in both vine growth and fruit production. At the initiation of the present tests in 1939, the vines involved were vigorous 6-year-old grafted vines that did not show foliage symptoms of little-leaf but did produce very loose, straggly clusters, resulting in low fruit production. Zinc deficiency symptoms are common in grapes and other fruits growing in the immediate vicinity of these tests.

Twelve vines were represented in each treatment and with the same number of check vines. All vines received the same cultural treatment. In 1939 the vines were pruned to eight 2-bud spurs, and in 1940 and 1941 ten 2-bud spurs were left per vine. The zinc sulphate solution was prepared at the rate of 2 pounds of commercial zinc sulphate to 1 gallon of water. This solution was brushed on the pruning cuts of the treated vines within an hour after pruning. The fresh cuts made in pruning were thoroughly wet with the solution. Vines were pruned and fresh wounds treated in January, February, and March of 1939, and in January and February of 1940 and 1941.

The condensed results are given in Table I. The effects of the zinc sulphate treatments on the Alexandria grape are tabulated according to the number of buds growing, the fruit yields, and the wood weights per vine, in comparison with the check vines for the various dates of treatment.

There appeared to be definite injury to the dormant buds on the treated vines under some conditions. This injury was determined by comparing the number of buds that grew on the treated vines with those on adjoining check vines that had been pruned to the same number of buds. The buds nearest the cut ends of spurs and hence nearest the points where the zinc sulphate solution was applied, designated as first buds, showed the most injury. This injury was more apparent on the first buds in the 1939 January treatment, with decreasing injury resulting from the February and March treatments of the same year. The January treatments of 1940 and 1941 also resulted in injury to the first buds of spurs. Fewer first buds grew on the treated vines of February 1940 and 1941 in comparison with check vines, the trend indicating some possible injury.

Injury to the second buds from the cut ends of spurs was definitely shown in the January-treated vines for all years. The treatments of

February and March 1939 resulted in fewer second buds growing per vine compared to check vines. While the trend seems to indicate injury, the data do not appear significant. The average number of second buds growing on the February-treated vines in 1940 and 1941, respectively, was nearly identical with the check vines and no injury was evident. Since injury to the dormant buds varied with the date of treatment, the condition of the vine at the time the zinc sulphate solution was applied may be an important factor for further study.

Table I indicates that the Alexandria vines treated with zinc sulphate solution gave greatly increased fruit yields over the check vines in all cases. The increased fruit yields apparently resulted from a better setting of berries on the fruit clusters at blossoming time. Fig. 1 illustrates the better clusters obtained and the comparative fruit yields of a treated vine on the right and a check or nontreated vine on the left. These vines were 8 feet apart in the row, pruned to the same number of spurs, and both received the same vineyard treatment with the exception of the zinc sulphate application. The fruit yields appeared to be affected by the time of treatment. The vines treated in January 1939 gave increased yields over the check vines, but due to the greater injury to first buds, did not yield as heavily as the February-treated vines of the same year. The vines treated in March 1939 produced slightly less than the February-treated vines, possibly due to greater sap activity at the March application of the solution to the vines. The fruit yields in 1940 and 1941 of the January treated vines were higher than those of the February-treated vines. The February-treated vines in 1941 yielded more than the comparable check vines but decidedly less than the treated vines of other dates. During the February treatment in 1941 the vines were quite moist and the lack of penetration of the solution may account for the lower yield obtained.

TABLE I—EFFECT OF ZINC SULPHATE ON THE ALEXANDRIA GRAPE

Date of Treatment	Average Number of Buds Growing Per Vine‡				Fruit Yields (Pounds Per Vine)		Wood Weights (Pounds Per Vine)	
	First Bud*		Second Bud**					
	Check	Treated	Check	Treated	Check	Treated	Check	Treated
1939								
Jan 9	7.5 ±.17	2.8 ±.28	7.1 ±.21	4.4 ±.19	17.3 ±1.70	30.5 ±2.29	4.5 ±.35	3.5 ±.39
Feb 1	6.8 ±.33	5.2 ±.22	6.9 ±.19	6.0 ±.27	18.5 ±2.22	42.2 ±1.41	4.4 ±.08	4.5 ±.29
Mar 1	7.0 ±.21	6.4 ±.32	7.0 ±.34	6.4 ±.35	19.3 ±1.46	33.9 ±1.01	3.5 ±.36	4.6 ±.32
1940								
Jan 22	9.4 ±.11	5.7 ±.45	9.0 ±.13	5.7 ±.45	8.3 ± .77	39.5 ±2.55	4.7 ±.33	4.1 ±.30
Feb 19	9.2 ±.17	8.5 ±.17	8.5 ±.23	8.6 ±.18	14.5 ±1.29	33.2 ±1.71	5.0 ±.25	4.3 ±.20
1941								
Jan 11	9.1 ±.27	6.4 ±.34	8.9 ±.19	7.6 ±.21	11.0 ±1.21	37.5 ±2.43	——†	——
Feb 17	7.7 ±.10	7.2 ±.12	7.4 ±.21	7.6 ±.12	18.0 ±1.28	22.4 ±1.49	——	——

*First bud from cut end of spur.

**Second bud from cut end of spur.

†Vines unpruned at time of report.

‡In 1939 there were 8 spurs per vine; in 1940 and 1941, there were 10 spurs per vine.

The vine growth, as judged by observations during the growing sea-

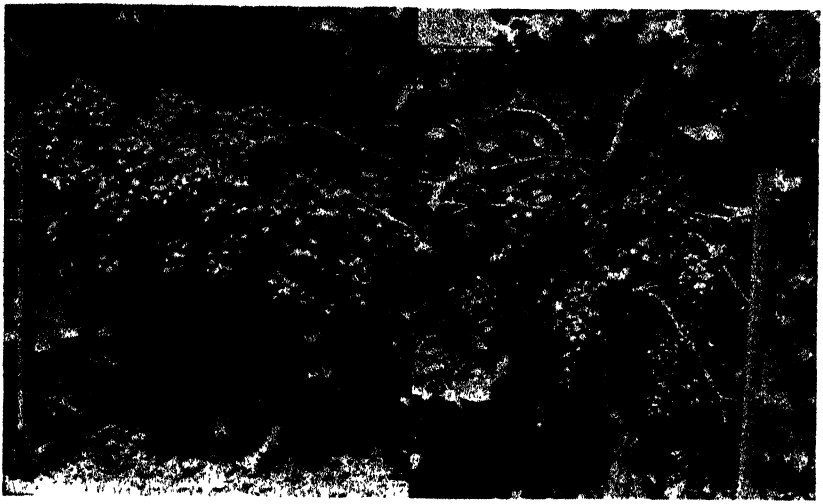

Fig. 1. Effect of zinc sulphate treatment on the Alexandria grape. Left, Treated vine, 44.3 pounds of fruit; right, non-treated vine, 9.7 pounds of fruit. These vines stand 8 feet apart and have received the same treatment except that the one on the right received the daubing of zinc sulphate solution on pruning cuts and the one on the left did not.

son and by the pruned woodweights at the end of each year, did not show a definite trend which might be attributed to the zinc sulphate treatments. The woodweights of the treated vines were similar to the weights of the check vine prunings. Even though buds were killed by the treatments the fewer shoots produced by the main buds did not appear more vigorous on the treated vines than on the check vines. The additional fruit production of the treated vines may have balanced any beneficial growth effect of the treatment. Since the shoots from adventitious buds were not thinned off, such shoots on the treated vines may have tended to equalize the woodweights.

The zinc sulphate treatments caused some injury to dormant buds on the spurs by reducing the number of buds producing growth. Even though some injury to dormant buds was observed, fruit yields were practically doubled by the zinc treatment under the conditions of these tests. The pruned woodweights at the end of the season were not diminished or increased apparently by the treatments although the extra fruit production may have curtailed the growth of the treated vines. These studies indicate that the poor setting of the Alexandria may be associated with zinc deficiency, even though leaf symptoms are not apparent. Similar Alexandria vines pruned and treated between January 15 can be expected to show beneficial effects on fruit yields from the zinc sulphate treatment.

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Effects of Leafhopper Feeding Injury on Apparent Photosynthesis and Transpiration of Grape Leaves

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ABSTRACT

This material will be published in full in *Plant Physiology*.

IN AN earlier report (2) the effects of apple leafhopper (*Typhlocyba pomaria*) feeding injury on photosynthesis and transpiration of apple leaves were described. Further studies with grape leaves have shown similar effects of feeding injury of Erythroneura spp. on photosynthesis, transpiration, rate of leaf-area-increase, and internal leaf structure. Potted Concord and Delaware plants were moved from the greenhouse into the special environment-control chamber (1) after each leafhopper feeding period where metabolism studies were made. From 15 to 30 leafhoppers per leaf were allowed to feed for 20-day periods. After the first 20-day period photosynthesis and transpiration were reduced from 25 to 70 per cent. Photosynthesis was usually affected more than transpiration. After the second 20-day feeding period the two processes dropped to almost nothing and the foliage largely abscised. While the check leaves on a separate set of Delaware plants were increasing about 800 per cent in total area, the leaves which were being fed upon by grape leafhoppers increased only 500 per cent. When the leafhoppers were removed from the upper third of the shoots where they were allowed to feed, the rate of leaf-area-increase of the test leaves again assumed a rate of increase approximately the same as the check leaves.

From the results as a whole it was important to note that there was not only a decrease in total leaf area of the injured foliage but that there also was a decrease in the efficiency per unit area of this foliage. Thus, for example, a 20 per cent reduction in the rate of food manufacture per unit area of leaf surface on a plant whose leaf area is reduced 30 per cent means that 70 per cent of the normal area is functioning at 80 per cent of the normal rate, so that the total carbohydrates produced by the plant is only about 56 per cent of the expected amount.

Injured grape leaves were sectioned and prepared for microscopic examination. In the first stages of feeding injury the palisade cells were emptied of their contents but the walls appeared normal. Where injury was severe the spongy mesophyll cells were injured as well, and most injured cells had begun to dry and collapse.

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Resistance of Grape Varieties to the Freeze of November, 1940

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THE November, 1940, freeze took its toll in terms of many dead or severely injured fruit trees throughout the Middle West. The injury to grapes, however, was not as disastrous as injury to fruit trees.

The variety vineyard at the Oklahoma Agricultural Experiment Station afforded an excellent opportunity to study the effect of the freeze on different varieties. The vineyard, most of which was planted 1933, comprises approximately 3 acres, 66 rows 190 feet long, with rows running north and south. There are 10 plants each of the majority of the 75 varieties in the vineyard, a larger number of the more important commercial varieties, and three to five plants of some of the newer varieties. The site is nearly level with a gentle slope toward the southeast, and on light sandy loam soil, ideal for grape production.

The crop in 1939 was heavy which resulted in cane growth slightly below normal. A top-dressing of approximately 1¾ tons per acre of chicken manure was applied in the spring of 1940, which restored normal vigor to the vines, although the crop this season was light. It is not believed that the chicken manure application was heavy enough to delay maturity, but the unseasonably high temperatures during October and early November prevented the cessation of vegetative activity in the grape vines as well as in fruit trees. Prior to November 10, 1940, temperatures remained above 60 degrees F and no frost had occurred to check plant growth. From recording thermometers located near the vineyard, the first freezing temperature occurred at 6:00 p.m. November 11, 1940. Other low temperatures were as follows: November 12, 7:00 a.m., 22 degrees F; 10:00 p.m., 20 degrees F; November 13, 4:00 to 7:00 a.m., 10 degrees F; 11:00 p.m., 13.5 degrees F; November 15, 4:00 a.m., 10 degrees F; 6:00 a.m., 8 degrees F; November 16, 7:00 a.m., 26 degrees F. Thus temperatures were continuously below freezing from 6:00 p.m., November 11, to 9:00 a.m., November 16, 1940.

Examination of canes in the spring of 1941 revealed wood in good live condition with dieback in the tips only slightly (if any) more serious than that observed in normal seasons. Although no counts were made, a number of buds were cut and examined for injury. This examination revealed a variation between varieties in the number of dead buds, and pruning practices were altered to compensate for this loss by leaving more buds per vine, thus preventing over pruning.

When shoots began to emerge, it was obvious that many varieties were more severely injured than examination of buds seemed to indicate. Vegetative growth was very irregular in some varieties where the primary buds were killed and shoots were arising from secondary buds. When shoot growths averaged about four inches in length, and it was evident there would be no further emergence, counts were made of several vines of every variety counting all of the buds left on the

TABLE I—GRAPE VARIETY RECOVERY FROM FREEZE OF NOVEMBER 11, 1940 (RECORD TAKEN MAY 3, 1941, AVERAGE SHOOT LENGTH 4 INCHES)

Variety	Row	No. of Vines	Total No. Buds Counted	Total No. Buds Growing	Average Per Cent of Live Buds	1940 Yield in (Lbs/Vine)	Harvesting Date
Rommel	44	5	333	286	85.9	8.9	8-7
Ripley	5	3	229	189	82.5	17.9	8-20
Mericadel	41	5	396	325	82.1	15.7	8-22
Bailey	46	5	336	274	81.5	16.9	8-13
Minnie	35	5	414	327	79.0	11.5	8-28
Edna	33	5	446	350	78.5	16.2	8-27
Goethe	59	4	294	224	76.2	*	9-11
Brocton	6	3	274	208	75.9	6.0	8-6
Wine King	39	5	423	313	74.0	6.7	8-7
R. W. Munson	41	5	442	324	73.3	6.7	8-7
President	54	5	346	251	72.5	1.8	8-2
Carmen	38	5	445	312	70.1	18.2	8-7
Moore	2	4	294	203	69.0	2.9	7-29
Backman	57	5	354	243	68.6	2.9	7-29
Concord	58	5	317	217	68.5	18.6	8-20
Green	22	5	472	323	68.4	15.3	7-29
Catawaba	27	5	401	268	66.8	20.5	9-10
Extra	49	5	456	300	65.8	24.9	8-20
Pocklington	27	5	428	278	64.95	3.1	9-11
Fredonia	14	5	313	202	64.5	18.2	8-6
Worden	17	5	368	237	64.4	12.0	8-20
Pontiac	5	3	236	150	63.5	14.6	8-20
Beacon	31	5	542	333	61.4	17.7	8-12
Hubbard	53	5	406	247	60.8	7.0	9-26
Delaware	28	5	438	262	59.8	13.2	8-23
Wayne	5	3	173	103	59.5	16.9	8-20
Moore	55	4	303	179	59.1	5.0	7-29
Last Rose	34	5	445	257	57.75	6.2	10-12
Diamond	29	5	391	211	53.96	14.5	8-12
Lucile	21	5	440	226	51.4	16.1	8-12
America	32	5	308	153	49.7	4.8	8-12
Armalaga	42	5	423	208	49.2	5.7	8-28
Sheridan	7	5	334	159	47.6	4.5	8-20
Ontario	24	5	355	162	45.6	10.8	7-25
Martha	26	5	345	142	41.15	10.1	8-30
Dunkirk	12	2	199	81	40.7	10.2	8-7
Hernito	37	5	377	150	39.8	5.3	8-7
King	18	4	326	127	38.95	14.7	8-20
Wapanuca	39	5	405	154	38.0	9.1	8-22
Vergennes	11	5	293	110	37.5	8.5	9-10
Salem	25	5	379	139	36.7	5.0	8-20
Eaton	11	5	374	135	36.1	3.5	8-26
Ronaldo	36	5	303	106	35.0	11.0	8-28
Gaertner	23	5	308	99	32.1	3.0	8-22
Ellen Scott	40	5	437	129	29.5	22.8	8-22
Portland	9	5	306	90	29.4	14.9	8-20
Cloeta	43	5	414	119	28.7	5.2	8-7
Campbell	56	5	413	117	28.3	4.2	7-29
Fern Munson	34	5	334	94	28.1	5.8	9-7
Captivator	25	5	312	87	27.9	17.1	8-22
Watkins	6	3	237	65	27.4	1.5	8-6
Hubbard	20	5	423	113	26.7	6.8	8-7
Golden Muscat	23	5	324	85	26.2	19.5	8-14
Moyer	7	5	365	92	25.2	5.5	8-7
Niagra	60	5	263	66	25.1	9.9	8-26
Caco	29	5	346	84	24.3	11.2	8-30
Jefferson	8	4	318	77	24.2	13.8	8-28
Urbana	5 and 20	7	504	102	20.2	8.6	9-10
Champion	17	3	174	34	19.5	12.7	8-23
Campbell	1	4	293	56	19.1	4.7	7-29
Hanover	5 and 12	7	533	99	18.5	2.3	8-20
Muench	37	5	382	66	17.3	11.6	8-28
Golden Muscat	16	5	375	64	17.1	18.5	8-19
Regal	10	5	317	48	15.1	16.1	8-30
Henryetta	15	4	382	48	12.6	2.1	8-7
Jessica	9	4	311	37	11.9	20.0	8-20
Brilliant	31	5	301	28	9.3	3.7	9-5
Scuppernong	61	3	4200†	191	4.6	—	—
Male Muscadine	61	3	3750†	133	3.6	—	—
Herbemont	35	3	318	11	3.5	4.4	9-11
Thomas (Muscadine)	61	3	2800†	51	1.8	—	—

*Heavy crop lost by bird damage.
†Portion of each vine counted, remainder estimated; vines unpruned.

TABLE I (*Concluded*)

Variety	Row	No. of Vines	Total No. Buds Counted	Total No. Buds Growing	Average Per Cent of Live Buds	1940 Yield in (Lbs/Vine)	Harvesting Date
James (Muscadine)...	61	3	4500†	20	.4	——	——
Daisy..............	—	10	——	0	0	14.2	8–2
Kenka..............	—	3	——	0	0	1.1	9–5
Mathilda............	—	10	——	0	0	12.5	8–7
Seneca..............	—	3	——	0	0	11.5	7–27
Stout Seedless.......	—	1	——	0	0	——	9–5
Vinifera Species	—	6	——	0	0	0.5	8–13
Winchell............	—	10	——	0	0	——	——

*Heavy crop lost by bird damage.
†Portion of each vine counted, remainder estimated; vines unpruned.

vine after pruning and the number of buds growing. No attempt was made to segregate primary and secondary shoots. The growth between vines within a variety was quite uniform according to observations and calculation of the data secured. These data are presented in Table I, including also the harvesting data for 1940.

An analysis of these data shows that eight varieties had less than 25 per cent of their buds injured, 30 varieties with less than 50 per cent and seven varieties with 100 per cent of the buds above the ground killed. Further analysis seems to indicate that such factors as location in the vineyard, yield and time of harvest had no measurable influence on resistance to freeze injury. The ten highest yielding varieties located in scattered sections of the vineyard and producing over 3 tons per acre, showed marked variation in resistance to injury, Table II.

TABLE II—RELATION OF LOCATION AND YIELD TO HARDINESS

Variety	Row	1940 Yield (Lbs Per Vine)	Per Cent Live Buds
Extra	49	24.9	65.8
Ellen Scott....	40	22.8	29.5
Catawba..	27	20.5	66.8
Jessica.................. . . .	9	20.0	11.9
Ontario.........	24	19.8	45.6
Golden Muscat..	23	19.5	26.2
Concord	58	18.6	68.5
Golden Muscat.....	16	18.5	17.1
Fredonia..............	14	18.2	64.5
Ripley..................	5	17.9	82.9

The 1941 crop was very light. An analysis of the harvesting data showed that of the five highest yielding varieties — Mericadel, Edna, Extra, Bailey, and Worden, in order of production — only a few vines produced more than one cluster per shoot indicating a high percentage of secondary shoot growth. It is interesting to note, however, that two of the above varieties, Bailey and Extra, are important commercial varieties in Oklahoma.

It is apparent that the differences recorded in resistance to early fall freeze injury were due to varietal characteristics.

As mentioned above, the freeze of November, 1940, was not as disastrous to grapes as to fruit trees since all vines, except very weak ones, that were severely damaged produced sufficient new growth from the crown to reconstruct normal framework within one or two years.

The Influence of Blossom Buds on Rooting of Hardwood Cuttings of Blueberry

By F. L. O'Rourke, *Soil Conservation Service, Glenn Dale, Md.*

TESTS are now being conducted in various hillculture plantings to determine the soil-conserving value of several species and strains of blueberries, their adaptability to site conditions, and the quality and abundance of their fruit. In general, blueberries have been rated highly for their soil retaining power. The interlacing underground stems or rhizomes, with the attendant roots, form a tightly-woven network just below the soil surface that effectively prevents both water and wind erosion, while above ground the spreading shoots break the force of dashing rains and allow gradual penetration to the soil below. Furthermore, the blueberry is able to survive in the early stages of plant succession, since it competes successfully with broomsedge and undesirable forbs and shrubs so commonly found on eroded or depleted soils.

Individual bushes vary widely in form of plant as well as in some of the fruit characteristics. Certain clones developed by selection or breeding are much superior to the type, and it seems highly desirable that such types be perpetuated by vegetative propagation. Though grafting, budding, layering, tubering, rhizome cuttings, and rooting from greenwood cuttings all have been employed, the practice most favored is rooting plants from hardwood stem cuttings, which are commonly collected and made during the late winter and inserted in the proper medium in the early spring. Johnston (1) working with cultivated varieties of *Vaccinium corymbosum,* stated that "hardwood cuttings are made from the new shoots produced the previous season . . . The upper third of most shoots is usually discarded, due to the prevalence of fruit buds."

The writer has observed that it was the practice of certain commercial propagators to cut off and discard any portion of the stem bearing fruit buds, although no reason was offered other than the statement that cuttings with blossom buds would not root. To determine whether it is the presence of the flower buds that decreases rooting, cutting material was collected from wild bushes of the downy high-bush blueberry, *Vaccinium atrococcum,* which grows profusely on the Soil Conservation Service tract at Beltsville, Maryland. Care was taken to insure a good mixture of all cuttings collected, so that clonal differences would not modify the results. Practically all the cuttings were made from the middle third of last season's growth. The upper third was discarded because that portion bears only flower buds, while the lower third was usually discarded on account of its larger diameter. In some cases these cuttings made from the middle third of last year's growth contained only leaf buds, while in other cases they carried both leaf and flower buds. The diameters of the cuttings were held to a rather narrow range, approximately 2 to 4 millimeters, and the length standardized to approximately 4 inches. As directed by Johnston (1), the lower cut was made immediately beneath a bud and the upper cut just above a bud.

Cuttings were made immediately after several collections of wood had been made during the latter half of March, and held in moist peat moss in cold storage until April 5, when they were set in a cold frame containing about 5 inches of a peat and sand mixture (about one-third German peat moss and two-thirds coarse bank sand). The frame was tile drained beneath and covered with glass sash and half and half lath shade to which burlap was nailed to offer greater protection. Tight ventilation was maintained until early July, when the sashes were raised gradually day by day until they were removed entirely in early September. The cuttings were removed and examined on September 11.

As the problem was to determine the effect of the flower bud on subsequent rooting, the cuttings had been grouped into three classes; (a) those bearing leaf buds only, (b) those bearing one or more blossom buds in addition to at least two good leaf buds, and (c) those bearing one or more blossom buds which were removed by rubbing, but the wood upon which they were borne allowed to remain on the cutting. The response is shown in Table I.

TABLE I—ROOTING RESPONSE OF THREE TYPES OF PREPARED HARDWOOD CUTTINGS OF *Vaccinium atrococcum*

Cuttings Bearing Only Leaf Buds		Cuttings Retaining One or More Fruit Buds		Cuttings with Fruit Buds Removed	
Number Set	Per Cent Rooted	Number Set	Per Cent Rooted	Number Set	Per Cent Rooted
20	50	20	0	20	5
20	35	20	10	20	5
20	55	20	10	20	5
20	40	20	0	20	5
20	40	20	10	20	0
20	45	20	0	20	5
20	45	—	—	20	0
20	15	—	—	20	5
20	50	—	—	20	20
20	35	—	—	20	15
20	40	—	—	20	0
20	45	—	—	20	15
240	42.1	120	5.0	240	6.6

Confirmation of the difference found between leaf bud and blossom bud cuttings is afforded by an additional lot set in another location of the same cold frame, although here only two types were used; namely, (a) those bearing leaf buds only, and (b) those bearing one or more flower buds in addition to two or more good leaf buds. The result of this experiment is shown in Table II.

The considerable differences in rooting found between cuttings on which blossom buds had formed and those on which they had not formed, and the small differences between those on which the blossom buds were retained and those from which they were removed, seem to indicate that it is not the presence of the flower buds that depresses rooting, but rather the conditions that lead to the formation of buds of this type. The extra labor involved in removing blossom buds from hardwood cuttings is not compensated by increase in rooting. Utiliza-

TABLE II—ROOTING RESPONSE OF TWO TYPES OF HARDWOOD CUTTINGS OF *Vaccinium atrococcum*

Cuttings With Leaf Buds Only		Cuttings With One or More Flower Buds	
Number Set	Per Cent Rooted	Number Set	Per Cent Rooted
40	58.5	40	0
40	37.5	40	0
40	35	40	0
40	30	40	0
40	20	40	0
40	37.5	40	0
40	60	40	0
40	52.5	40	0
40	25	40	0
360	39.4	360	0

tion of flowering wood, therefore, seems inadvisable, even in extreme scarcity of available cutting material.

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The Effect of Mulch on Soil Moisture, Soil Temperature, and Growth of Blueberry Plants

By F. B. Chandler and I. C. Mason, *Maine Agricultural Experiment Station, Orono, Maine*

DURING the past two years the authors have studied plots in three locations to determine the effect of mulch on soil moisture, soil temperature, and the growth of high-bush blueberry plants. In all three locations plants were grown under mulch and under clean cultivation. In one of these locations a few plants were also grown with a constant water table 24 inches below the surface of the ground. In another location one plot under sod mulch was included. The soil in these three locations were all different; at Monmouth it was a sandy loam; at Cherryfield it was a clay loam and at Deblois it was a very sandy soil. Tensiometers (2 and 4) were used to measure the soil moisture and the results are expressed as capillary tension in centimeters of mercury. Soil temperatures were measured with thermometers, the bulbs of which were 6 inches below the surface of the ground. The majority of the plants were set as 2-year-old plants in the spring of 1940 (a few skips and United States Department of Agriculture

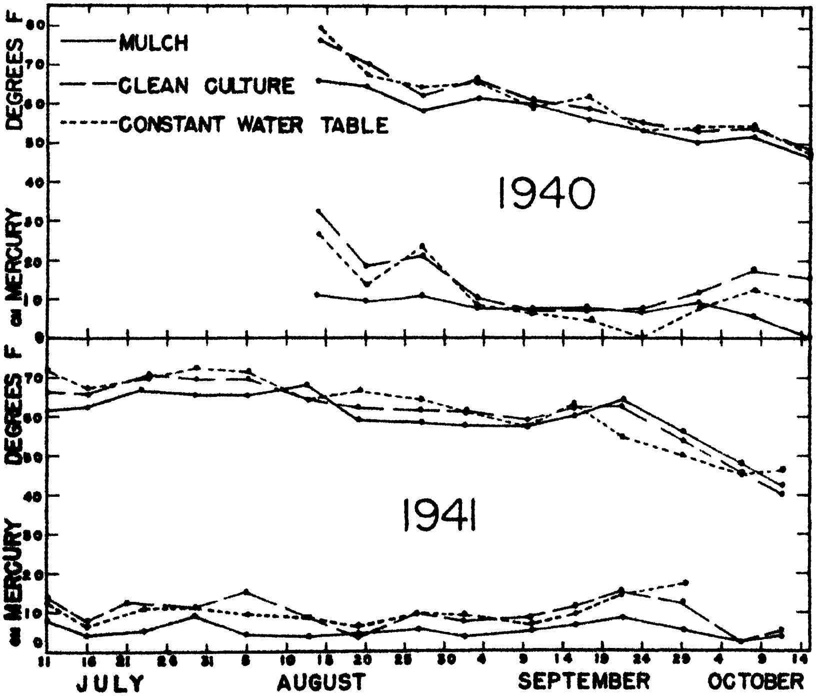

Fig. 1. Temperature in degrees Fahrenheit and soil moisture expressed as centimeters of mercury tension for Deblois soil 6 inches below the surface under mulch, clean cultivation and constant water table.

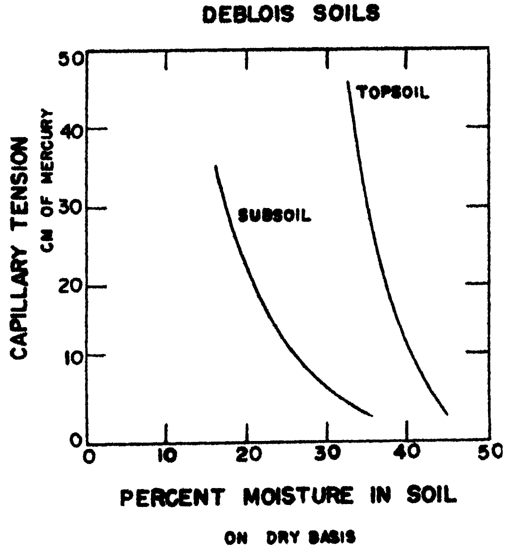

FIG. 2. Graphical relation between per cent moisture in Deblois soil and capillary tension of mercury.

varieties No. 3 and No. 73 were set in 1941.) The data have been analyzed by analysis of variance except the study of the blueberries grown with constant water table which was analyzed by "Student's" method. Odds of 19:1 have been considered significant.

Soil moisture was studied in only two of the locations and in both of these the mulch plots exerted significantly less tension on the mercury column than the clean culture plots. The difference necessary for significance between means was 4.56 centimeters with a mean for 6 inches below the surface in mulch of 12.28 and 8.98 centimeters and in clean cultivation of 19.12 and 17.36 centimeters, sandy loam and sandy soil respectively (see Fig. 1). The data also show that the mulch plots had more moisture than clean culture 12 inches below the surface. There was a difference in the tension on the mercury column of the two types of soil but the difference was not significant except in clean cultivation 12 inches below the surface where the sandy loam soil had a pull of 17.02 centimeters and the sandy soil had a pull of 9.22 centimeters. The sandy soil which had a water table maintained 24 inches below the surface had more moisture at the 12-inch level than clean culture but there was not a significant difference at the 6-inch level. The mean moisture content based on the dry weight of the soil was 42 per cent for the mulch plot and 38 per cent for clean culture (see Fig. 2).

In the study of temperature a grass sod was included with the plots previously mentioned for the moisture studies. The mean temperature for sod and mulch were not different (63 and 65 degrees F) but both had a lower temperature than clean culture (70 degrees F; difference necessary for significance between means 3.27). The mean temperature of the plot with a constant water table was the same as the temperature of the plot with clean cultivation. The mean temperature of the mulch plots in the two locations were not significantly different.

A study of the growth of Rubel in the three localities shows a significantly greater growth in Monmouth than in the other locations. When all the varieties in each location were averaged a decrease in the amount of growth with an increase in the amount of fertilizer was frequently observed. However, Deblois was the only locality where this decrease

TABLE I—MEAN LINEAR GROWTH OF BLUEBERRY PLANTS BY LOCALITIES AND TREATMENTS WITH THE DIFFERENCE NECESSARY FOR SIGNIFICANCE

Soil Type	Treatment		Mean Linear Growth (Cms)	Difference Necessary for Significance (Cms)
	Culture Method	5-8-7 Fertilizer (Pounds per Acre)		
		Deblois		
Sandy	Clean	1000	313.6	36.1
	Clean	1500	279.6	
	Clean	2000	167.3	
	Mulch	1500	190.7	
		Cherryfield		
Clay loam	Clean	1000	217.9	88.6
	Clean	1500	146.5	
	Mulch	1000	325.4	
	Mulch	1500	308.4	
		Monmouth		
Sandy loam	Clean	1000	358.3	68.5
	Clean	1500	360.9	
	Mulch	1000	308.2	
	Mulch	1500	280.5	

could be considered significant (see Table I). Fertilizer burning may have caused the decrease in growth as it was observed on other plants in the State but no symptoms were observed on blueberries. The growth of blueberries in the mulch plots on the sandy and sandy loam soils was less than in clean culture. However, in the clay loam plants grew more in the mulch than in clean cultivation. Clark (1) reported an increase in growth and yield with mulch on upland soils. Increase of yield was also reported by Kramer *et al* (3) with mulch in Maryland.

We may conclude by stating that mulch retains the soil moisture, keeping the mean above that for clean cultivation; maintains a lower soil temperature; reduces the growth of blueberry plants in sandy soils; and increases the growth of blueberry plants in clay loam.

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Growth Response of Blueberries Under Clean Cultivation and Various Kinds of Mulch Materials[1]

By Earl F. Savage, *Georgia Agricultural Experiment Station, Experiment, Ga.,* and George M. Darrow, *U. S. Horticultural Station, Beltsville, Md.*

COMMERCIAL blueberry growing is a comparatively new industry in this country, and there has been very little research to determine those cultural practices which give the best growth response consistent with good yields. For the most part the older blueberry plantings have received clean cultivation, and there is very little available information on the possibilities and effects of different kinds of mulch materials. This experiment was set up so that data could be obtained on the adaptability of various seedling progenies to northwest Georgia as well as to determine the effect of different mulches as compared with clean cultivation on the growth of these seedlings. It is the latter phase of this experiment which is now being reported.

Methods and Materials

The planting on which these data were obtained is located near Sugar Valley in northwest Georgia on a Clarksville gravelly loam soil. This soil is quite friable both in the top and subsoil and would be classified as a good agricultural type. Chemical tests of this soil before planting showed it to be well supplied with available nitrogen and potash but somewhat deficient in phosphate. The pH of the soil ranged from 5.4 to 5.6. The slope of the land is about 6 per cent in a northeasterly direction. Three sides of the field are bounded by woods about 30 feet back from the outside rows of the planting. It is doubtful, however, that these woods affected the blueberry plants since the plots made an unusually good growth.

The plants used in these tests were hybrid seedlings of seven different progenies but all of high-bush parentage. They were set 4 by 4 feet in April 1939. The planting was so arranged that each progeny received each of the differential treatments except that only the three progenies listed in Table I were mulched with straw. There were at least 16 plants in each progeny group with the majority of the progeny groups containing 24 plants. The seven progenies were used as replicates.

The treatments used were clean cultivation, sawdust mulch, oak leaf mulch, and rye straw mulch. The mulches applied at the time of planting were approximately 3 inches in depth after settling. The sawdust was a mixture of hardwood and pine and had been weathered for at least 1 year. The clean cultivated plots were cultivated shallowly and often enough to keep the weeds under control. The first year ¼ pound of cottonseed meal was applied around each plant, but in subsequent years a complete fertilizer (8–8–6) was applied during March

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[1] The authors are indebted to Mr. T. W. Malone, Sugar Valley, Georgia, for the care given this planting and to Professor E. B. Morrow of North Carolina State College, Raleigh, North Carolina, for assistance in taking the data.

TABLE I—AVERAGE GROWTH RESPONSE OF BLUEBERRY SEEDLINGS UNDER CLEAN CULTIVATION AND DIFFERENT MULCHES AT SUGAR VALLEY, GEORGIA*

Treatment	Progeny 3701 Stem Length (Feet)	Progeny 3703 Stem Length (Feet)	Progeny 3704 Stem Length (Feet)	Average Stem Length (Feet)
Clean Culture				
Before pruning	11.9	32.3	30.1	24.4
After pruning	3.5	11.9	11.6	9.0
Sawdust Mulch				
Before pruning	80.8	247.5	160.9	196.4
After pruning	77.7	88.1	81.4	83.4
Oak Leaf Mulch				
Before pruning	84.3	103.0	101.7	96.3
After pruning	50.9	51.3	51.3	51.2
Rye Straw Mulch				
Before pruning	99.4	128.1	101.0	109.5
After pruning	48.1	63.3	41.6	51.0

*Progeny 3701 = Weymouth × Crabbe 4; progeny 3703 = Dixi × GS-149; progeny 3704 = Dixi × Jersey.

at the rate of ¾ pound per plant, followed in July by a sidedressing of ½ pound of sulphate of ammonia per plant.

In obtaining the data presented in Table I the two largest plants of each of three crosses were selected from each treatment and the total linear growth measured. This represented the growth produced during the first three growing seasons. The plants were then pruned and again measured to show the amount of shoot growth remaining after thinning out the weak wood. It was thought that the pruned bushes might best picture the productive capacity of plants under the different treatments. The difference beween the treatments was so apparent that it was not considered necessary to measure more plants to express the growth response numerically. Plant survival counts were made for all progenies under the different treatments.

RESULTS

All the plants from mulched plots were superior to those from the clean cultivated plots (Table I). The sawdust mulch was definitely superior to either oak leaves or rye straw, but there was little difference between the growth response under the oak leaf and rye straw mulches. At the end of the third year there were 95.2 per cent, 93.0 per cent, 79.7 per cent, and 68.7 per cent of plants alive under the sawdust, oak leaf, and rye straw mulches, and the clean cultivation treatments, respectively. On the basis of plants surviving, the sawdust mulch was definitely superior to rye straw mulch and to clean cultivation, and slightly superior to oak leaf mulch.

Plant survival and plant growth are both important to the productive capacity of a blueberry field. The plants in the clean cultivated plots were so small at the end of the third growing season that commercially their productive capacity would be zero. Integrating plant growth and plant survival the productive capacity of the plots under the three mulches is estimated at 100 per cent for sawdust, 54 per cent for oak leaf mulch, and 41 per cent for rye straw as compared with zero for clean cultivation. This estimated productive capacity is for the fourth and later growing seasons.

CONCLUSIONS

Mulching in one form or another is essential to obtain the best growth of highbush blueberries in northern Georgia under the prevailing conditions of high temperature and oftentimes deficient soil moisture. Sawdust mulch because of its greater power for retaining soil moisture by reducing surface evaporation and run-off was by far the best mulch under the conditions of this experiment. The looser forms of mulch, such as rye straw and oak leaves are much better than clean cultivation but cannot be considered as effective as sawdust mulch. Since sawdust is often the most easily obtainable and cheapest mulch in the Southeast, its use is to be recommended on such plants as blueberries.

Effect of Soil Media, Photoperiod and Nitrogenous Fertilizer on the Growth of Blueberry Seedlings

By FRANK PERLMUTTER[1] and GEORGE M. DARROW, *U. S. Horticultural Station, Beltsville, Md.*

IN a breeding program for improving the varieties of blueberries, any method of shortening the interval between seed germination and fruiting of the progeny would be of practical value. Ordinarily seedlings do not fruit before the third or fourth year after field planting or the fourth to fifth year from seed. A reduction of this time by 1 or 2 years would be of obvious importance. In this study the effects of soil media, photoperiods, and nitrogenous fertilizer were investigated with a view to producing large plants quickly.

MATERIALS AND METHODS

The blueberry seedlings used in this study were obtained from cross-pollinations made at the United States Horticultural Station, Beltsville, Maryland, in the spring of 1940. The fruits from these pollinations were harvested in June 1940 and the cleaned seeds were stored dry in small vials at approximately 40 degrees F until planted on September 6, 1940. Comparable greenhouse conditions of temperature, light and moisture were given all of the plants, the only variable being the treatments outlined below. The seedlings were up and transplanted into 2-inch thumb pots during the first week of November 1940 after two to four true leaves had developed.

For the soil media experiments the very young seedlings were transplanted directly from the seed flats into eight different soil mixtures listed in Table I. The pH of each medium was obtained at the start of these experiments and again at the time of planting in the field (Table 1). Total linear stem growth and leaf area measurements were made

TABLE I—EFFECT OF SOIL MEDIA ON THE GROWTH OF BLUEBERRY SEEDLINGS (AVERAGE OF 25 SEEDLINGS IN EACH LOT; LINEAR GROWTH IN CENTIMETERS WHEN PLANTS WERE TAKEN TO THE NURSERY MAY 1941)

Soil Media		pH in		Myers ×Black Giant (Cms)	*Vaccinium* sp. N.C. ×Pecan × Self (Cms)	*V. Tallapusae* ×Stanley-A (Cms)	*V. Tallapusae* ×Stanley-B (Cms)	Average 100 Seedlings (Cms)
Number		Nov	May					
1	Forest litter	4.0	4.8	65	63	43	40	53
2	⅔ forest litter, ⅓ soil	4.7	5.7	74	86	70	51	70
3	⅔ forest litter, ⅓ sand	4.2	5.2	55	63	40	36	48
4	½ forest litter, ½ sand	4.3	5.3	37	43	31	37	37
5	½ forest litter, ½ soil	5.1	5.7	65	58	60	47	58
6	⅓ forest litter, ⅔ soil	5.4	5.7	53	39	58	40	48
7	⅓ forest litter, ⅓ soil ⅓ sand	4.7	5.7	63	62	61	43	57
8	Soil	6.0	6.2	21	17	20	26	21

Significant difference between parental lines (19:1) =22.9.
Significant difference between soil media (19:1) =4.8.

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[1] Now Soil Conservation Service, Sanford, N. C.

at regular monthly intervals throughout these studies. For each of the eight mixtures 100 comparable seedlings were used (25 seedlings of each of four lots, Myers x Black Giant, (*Vaccinium sp.* N.C. x Pecan) x self, *V. tallapusae* x Stanley-A (plant 9 open pollinated), and *V. tallapusae* x Stanley-B (plant 2 open pollinated).

For the light experiments 50 seedlings of the cross Dixi x AH-78 (lowbush x highbush selection) were used for each photoperiod, 25 of these seedlings being grown in a soil mixture of equal parts of forest litter, sand and soil (soil medium No. 7), and 25 in a mixture of two-thirds forest litter and one-third sand (soil medium No. 3). The photoperiods were natural daylight vs normal daylight supplemented by light from 200-watt Mazda bulbs 30 inches above the plants from sunset to 10:30 p.m. for 1, 2, 3, 4, or 5 months, all ending April 1. The natural daylight periods for Beltsville, Maryland, are approximately

9.7 to 10.6 hours for November
9.6 to 9.7 hours for December
9.6 to 10.2 hours for January
10.2 to 11.3 hours for February
11.3 to 12.6 hours for March

Due to drought conditions the seedlings were kept in the greenhouse until the latter part of May, when they were planted in the field. The last measurements were taken September 15 near the end of the growing season.

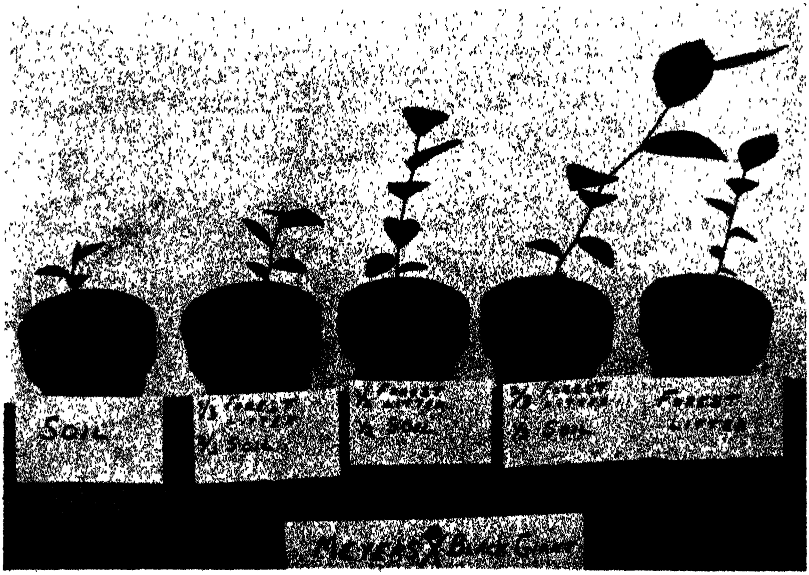

Fig. 1. Representative blueberry seedlings of the Myers x Black Giant cross in five of the eight different soil medio. To left, potting soil; to right, forest litter; and varying proportions of the soil and forest litter between (February 1, 1941).

RESULTS OF SOIL MEDIA EXPERIMENT

The effect of different soil media on the growth of blueberry seedlings is well illustrated in Fig. 1. The difference in growth of Myers x Black Giant seedlings is clearly evident at the early stage shown. The plant in the two-thirds forest litter plus one-third soil mixture is much larger than the others. The total lineal growth of each lot of seedlings is shown in Table I and in the charts in Fig. 2. One month after transplanting the seedlings to pots from the seed flats the plants in two-thirds forest litter and one-third soil were making the best growth. Greater linear growth and leaf area for this lot were maintained during each monthly period that measurements were made.

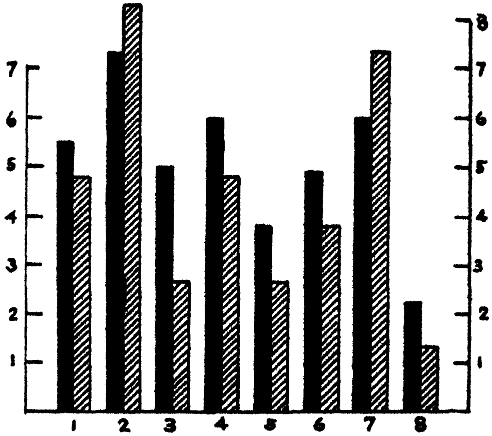

FIG. 2. Relative growth as measured by stem length and by leaf area of blueberry seedlings in eight different soil media, November 1 to May 1. (Average of 100 seedlings for each soil medium.)

Solid column = Height in centimeters
Cross-hatched column = Leaf area in square inches

1 = Forest litter
2 = 2/3 forest litter plus 1/3 soil
3 = 2/3 forest litter plus 1/3 sand
4 = 1/2 forest litter plus 1/2 soil
5 = 1/2 forest litter plus 1/2 sand
6 = 1/3 forest litter plus 2/3 soil
7 = 1/3 forest litter plus 1/3 soil plus 1/3 sand
8 = Soil

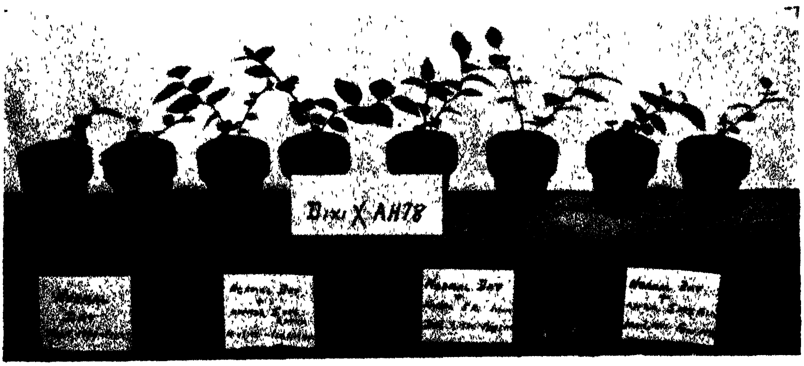

FIG. 3. Representative seedlings of Dixi x AH-78 (highbush x lowbush hybrid) grown under four light conditions. To left, two plants under normal light of winter; next two plants, 5 hours additional light daily for 3 months; next two plants, extra light for 2 months, and at right, two plants with extra light for 1 month (Photographed February 1.)

At odds of 19 to 1 a difference of 4.8 centimeters in linear growth for the eight soil media and a difference of 22.9 centimeters for the four parental lines is significant. An examination of the data shows highly significant differences between many of the different soil media (see last column Table I). Within parental lines slow-growing seedlings such as *Vaccinium tallapusae* x Stanley were not affected by the soil media to as great an extent as were the more vigorous seedlings of either *V. sp. N.C.* x Pecan or Myers x Black Giant. For the most part the different parental lines responded in about the same way to the different soil media.

RESULTS OF PHOTOPERIOD EXPERIMENT

The differential growth of young potted blueberry seedlings (Dixi x AH-78) made from November to February for 4 photoperiods is shown in Fig. 3. The advantage of a long day is clearly shown at this early stage (February 1). Plants growing under natural day were small with small leaves, while the plants under supplemental lights since November (for 3 months) and since December (for 2 months) were vigorous, large, stocky, and had many large leaves. The seedlings under supplemental lights for the month of January only were intermediate in size. Table II gives the data for plants April 1, after 2 additional months growth under supplemental light, as well as for another 2 months without supplemental light.

The response of blueberry seedlings to a longer day was first shown by Perlmutter (1). In that study the difference between dry weight

TABLE II—GROWTH OF BLUEBERRY SEEDLINGS IN TWO SOIL MIXTURES FOR SIX PHOTOPERIOD EXPOSURES (AVERAGE THREE SEEDLINGS FOR EACH LEAF AREA AND TWENTY-FIVE SEEDLINGS FOR EACH STEM OR LINEAR GROWTH MEASUREMENT)

Natural Daylight for Five Months Plus Supplemental Lights For	Soil Media Number	April, 1941, When Lights Were Stopped		May, 1941, When Plants Were Taken to the Field			Sept 15, 1941, at End of Growing Season	
		Leaf Area (Sq In)	Linear Growth (Cms)	Leaf Area (Sq In)	Increase in Leaf Area April to May (Per Cent)	Linear Growth (Cms)	Total Linear Growth Sep 15 (Cms)	Increase in Linear Growth May to Sep 15 (Per Cent)
0 months	7	12.6	37	25.4	101.8	54	94	74
	3	8.3	26	27.6	233.8	42	—	—
1 month (March)	7	12.9	28	30.6	138.4	49	215	341
	3	7.6	24	25.4	232.7	47	173	272
2 months (February and March)	7	17.5	35	37.6	115.2	60	—	—
	3	12.5	31	38.1	205.6	61	—	—
3 months (January to March)	7	25.9	52	38.5	48.5	80	232	305
	3	14.2	37	31.5	122.5	55	158	187
4 months (December to March)	7	39.5	65	53.3	34.8	93	278	200
	3	23.2	47	33.0	42.4	69	191	175
5 months (November to March)	7	39.1	63	57.9	47.8	89	—	135
	3	23.1	50	45.7	98.0	77	—	105
Difference necessary for significance between photoperiod treatments at odds: 19 to 1		9.8	10.0	14.4	—	18.8	—	—
Difference necessary for significance between soil mixtures at odds: 19 to 1		—	—	—	—	—	59	

of plant parts (root and shoot) or for the total plant was highly significant for the photoperiod treatment.

For the best soil mixture No. 7, the data in Table II shows a significant difference in total stem growth and in leaf area due to supplemental light for the 3-, 4-, and 5-month periods as compared with the natural day, the 2-month or the 1-month periods. Both the 4- and the 5-month periods of supplemental light were also significantly superior to the 3-month period. In general these differences continued through April and up to the time the plants were set in the field, late in May, even though supplemental lights had been discontinued. However, the per cent increase in leaf area for this period was much less for the plants that had been under the 3-, 4- and 5-month long photoperiods than for the natural day and 1- and 2-month long photoperiods. Plants receiving 1 or 2 months of supplemental light late in winter were not significantly better than those receiving the natural light of winter only.

For the plants in the poorer soil mixture (number 3) of two-thirds litter and one-third sand the general trend was the same as with plants in the better soil but the growth was much less and the differences between the different lots were not so marked. Data on number of leaves per plant were taken but the number of leaves was not significantly different for the six photoperiods.

Table II gives the percentage increase in stem growth for the same plants, started in the two soil mixtures and under four photoperiods, after they had been in the field for one growing season. The plants which had been given supplemental light all made a greater increase in growth than did the natural-day plants. A long day even for as short a period as 1 month had a remarkably stimulating effect on the later growth in the field. In fact these 1-month photoperiod plants, which were not significantly larger than the natural-day plants when they went to the field in May, had over twice the stem growth 4 months later. This stimulating effect was greater for the 1- and 3-month photoperiod lots than for the 4- and 5-month lots.

RESULTS OF NITROGEN EXPERIMENTS

Tests were made of urea, of nitrate of soda and of ammonium sulfate on the small blueberry seedlings growing in pots in the greenhouse. Urea (1 gram per liter of water) applied once, two, three, or four times at weekly intervals to two soil mixtures gave no significant increases in growth. Similar applications of nitrate of soda or of ammonium sulfate applied to the eight different soil media tested for blueberry seedlings did not give significant increases. Under the conditions of the tests, these nitrogenous fertilizers were not effective in causing increased growth.

SUMMARY

Leaf area and total linear growth measurements on blueberry seedlings growing in eight different soil media showed that a mixture of two-thirds forest litter with one-third potting soil was best for growth. The vegetative growth of blueberry seedlings was greatly increased by

extending the photoperiod during the short days of winter. The final size of the plants at the end of the season was in general proportional to the number of months of supplemental light which they had received. Supplemental light for as short a period as 1 month in March had a stimulating effect on the following season's growth of the blueberry in the field and this stimulating effect in the field was greater for the 1- and 3-month photoperiod plants than for the 4- and 5-month ones. No significant difference was evident in the average number of leaves per plant due to exposure to various monthly light periods. However, there was a significant difference in leaf area. No significant increase in growth of blueberry seedlings was obtained by application of nitrogenous fertilizers such as urea, nitrate of soda, or ammonium sulfate during an early stage in the life history of the seedling.

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Selection of Criterion Leaves for the Identification of Blueberry Varieties[1]

By J. HAROLD CLARK and S. G. GILBERT, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

IN a previous report (3) a method for the rapid measurement of certain dimensions and angles of blueberry leaves was described. The use of such measurements in the classification of blueberry varieties was discussed and a preliminary key to varietal identification was proposed. This key was based on measurements of "the largest leaves, one to three from a twig, taken from near the tip". Such leaves appeared to the eye to be satisfactorily representative of the variety. It seemed advisable for two reasons, however, to make some additional studies as to the best method of selecting criterion leaves. In the first place it is planned to further refine and expand the key to include new varieties as they appear, hence the most accurate method of leaf selection should be employed. In the second place because of the increasing use of actual leaf measurements and ratios in varietal identification within certain species (1, 2, 4, 5, 6) additional data on variability of leaf shape should be of value.

Blueberry leaves on lateral shoots range in size from very small near the base of the shoot to a maximum size just back of the tip, with one to three smaller leaves beyond the zone of maximum size. On shoots of uniform size leaves from any one location on the shoot might be considered as typical of the variety if compared with leaves of other varieties from similar locations. It would seem best, however, to standardize on the location producing leaves showing the least variability within the variety for the selection of criterion leaves to be considered as most typical of the variety. These studies were designed primarily to locate the zones of least variability.

METHODS OF SELECTING CRITERION LEAVES ON THE TWIG

Ten lateral shoots were selected in September, 1941 from vigorous, bearing age plants of each of five blueberry varieties growing on the Horticultural Farm at New Brunswick, N. J. The shoots were 8 to 12 inches long, with no secondary growth, and bore 12 to 22 leaves each. They were selected from the upper part of the bush, care being taken to avoid both upright leaders and drooping shoots around the lower part of the plant.

The leaves on each twig were arbitrarily divided into four approximately equal groups and numbered consecutively with the first group comprising the leaves nearest the base and the fourth group including those at the tip. If the total number was divisible by four, each group contained one-fourth of the total number of leaves on the twig; if there was one odd leaf, it was placed in the first quarter, if two, one leaf was placed in each of the first two quarters, if three, one was placed in each of the first three quarters. A fifth group was made to include the fourth, fifth, and sixth leaves from the twig apex. The data obtained for the widest leaf from each twig were included as a sixth group.

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[1] Journal Series Paper of the New Jersey Agricultural Experiment Station, Department of Pomology.

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The leaves were all measured individually after which the coefficient of variation was calculated for the leaves in each group. The results for each of the indicated measurements for the five varieties studied are shown in Table I. The ratios of the tip/base angle measurements and leaf width/length were also calculated.

TABLE I—COEFFICIENTS OF VARIATION OF LEAF MEASUREMENTS BY SELECTED GROUPS ON THE TWIG

Group	Adams	Grover	Harding	Rancocas	Rubel
		Tip Angle			
Quarter No. I	7.5±1.3	10.7±1.6	7.3±1.1	9.7±1.5	8.8±1.2
Quarter No. II	5.9±0.7	6.7±0.7	5.9±0.7	8.5±1.0	6.7±0.7
Quarter No. III	5.0±0.6	6.2±0.6	6.8±0.7	4.9±0.5	3.5±0.4
Quarter No. IV	4.4±0.5	5.5±0.6	7.3±0.8	4.8±0.5	4.1±0.4
Leaves—4-5-6	3.7±0.5	4.9±0.6	5.3±0.7	5.0±0.6	3.3±0.4
Widest Leaf	5.4±1.0	6.1±1.1	8.6±1.7	4.6±0.8	4.8±0.8
		Base Angle			
Quarter No. I	8.3±1.4	10.7±1.6	13.5±2.0	10.8±1.6	10.2±1.4
Quarter No. II	6.7±0.8	8.3±0.9	8.0±0.9	8.9±1.0	7.2±0.8
Quarter No. III	5.1±0.6	10.4±1.1	5.0±0.6	5.1±0.6	4.8±0.5
Quarter No. IV	5.1±0,5	8.7±0.9	7.7±0.8	6.2±0.7	4.5±0.5
Leaves—4-5-6	3.4±0.4	9.2±1.3	5.8±0.7	5.1±0.7	3.9±0.5
Widest Leaf	4.2±0.7	9.4±1.7	6.2±1.2	3.3±0.6	3.2±0.5
		Tip/Base Angle Ratio			
Quarter No. I	9.5±1.5	4.3±0.6	8.0±1.2	5.1±0.8	4.2±0.6
Quarter No. II	8.0±1.0	5.1±0.6	6.9±0.8	3.7±0.4	4.8±0.5
Quarter No. III	4.9±0.5	9.0±0.9	8.1±0.9	4.3±0.5	5.5±0.6
Quarter No. IV	3.4±0.4	7.6±0.8	9.6±1.0	6.0±0.6	4.6±0.5
Leaves—4-5-6	3.2±0.4	7.4±1.0	8.3±1.0	4.9±0.6	4.8±0.6
		Width			
Quarter No. 1	29.4±4.3	12.6±1.4	38.9±5.9	30.3±4.0	31.0±3.7
Quarter No. II	12.3±1.5	4.9±0.5	18.2±2.2	15.7±1.9	10.8±1.2
Quarter No. III	8.8±1.0	2.4±0.3	8.7±0.9	7.4±0.8	8.5±0.9
Quarter No. IV	6.6±0.7	4.0±0.4	9.5±1.0	10.4±1.1	9.1±0.9
		Length			
Quarter No. I	34.4±4.7	38.1±8.3	39.7±5.5	34.2±4.5	35.9±4.1
Quarter No. II	9.5±1.1	11.8±1.3	16.2±2.3	10.6±1.2	6.0±0.7
Quarter No. III	6.4±0.7	8.4±0.9	8.8±1.0	4.6±0.5	6.5±0.7
Quarter No. IV	6.0±0.6	12.4±1.3	7.9±0.9	11.4±1.2	9.0±0.9
		Width/Length Ratio			
Quarter No. I	15.8±2.4	12.0±1.5	13.6±1.7	10.7±1.3	18.3±2.1
Quarter No. II	5.4±0.6	6.7±0.7	6.0±0.7	8.4±1.0	6.8±0.7
Quarter No. III	6.0±0.7	8.3±0.9	2.6±0.3	5.9±0.6	5.4±0.6
Quarter No. IV	5.6±0.6	7.0±0.7	5.8±0.6	8.9±1.0	5.2±0.5
Leaves—4-5-6	5.5±0.7	5.8±0.8	4.8±0.6	2.5±0.3	7.6±1.0

It is evident from the data for the five varieties studied that the leaves near the base of the twig are most variable as to angles and dimensions studied, with groups III and IV less variable than group II. The width/length ratio is also quite variable near the base of the twig. The tip angle/base angle ratio, however, shows somewhat less variability that can be associated with position of the leaf on the twig. The data, all varieties considered, do not indicate that any one of groups III, IV, 4–5–6, or widest leaves would be significantly less variable than the others so that measurements of any of these groups could be considered as typical of the variety if the same group were always used. When ratios are considered, there is much less variability, as between groups, than when single measurements are considered.

In order to standardize procedure it is recommended that, for purpose of variety identification, the leaves be chosen from the fourth to the sixth nodes from the tip of the twig when more than 12 leaves are present. Twigs with fewer leaves should be avoided in the selection of criterion leaves.

It is evident from Table I that certain measurements show a higher degree of variability than others. For instance, the tip angle measurements of all leaves on the twig, or of the 4–5–6 group, are less variable than base angle measurements. Leaf width and length are much more variable than the angles, as would be expected, since these dimensions (leaf size) are so easily affected by variations in plant vigor. When it comes to ratios, however, the leaf width/length ratio is much less variable than width or length alone and only slightly more variable than tip/base angle ratio. In fact when group 4–5–6 alone is considered the leaf width/length ratio is slightly less variable in this particular experiment, than tip/base angle ratio. In certain cases it might be desirable to use all these measurements in distinguishing between two varieties inasmuch as it requires little more time to measure tip and base angles, leaf length and leaf width with the Blueberry Leaf Gauge than it does to make any one measurement. The most valuable measurements appear to be tip angle, base angle, and leaf width/length ratio. The tip/base angle ratio would be satisfactory to use but it involves extra calculation and in most cases might not be necessary.

Comparison of Measurements for Two Years and from Two Sources

Any system of classification, to be of value, must involve characteristics which are not markedly affected by the location of the plants. It is interesting to compare, therefore, measurements made in 1940 in New Jersey with those made in 1941 in both New Jersey and Massachusetts although the New Jersey 1941 criterion leaves were selected more rigidly than were the others, being limited to group 4–5–6. Table II shows the mean measurements for five varieties.

It is evident from the Table II that there is no significant difference between the measurements for the two seasons as a difference of less than 10 per cent could not be considered significant with these small samples in view of the variability shown in Table I. The data for plants from Massachusetts also are in close agreement with those obtained from New Jersey. The data in both Tables I and II indicate the Grover variety to be somewhat more variable as to leaf shape than the other varieties studied.

THE EFFECT OF VARIATIONS IN VIGOR ON LEAF CHARACTERISTICS

Certain leaf samples (not included in Tables I and II) were obtained from comparatively weak plants growing in soil deficient in nutrients, especially nitrogen. On such soils leaf width and length would obviously be relatively small but the data indicate that the leaf width/length ratio is not greatly different from that obtained with leaves from more vigorous plants. The tip angle seems to be only slightly affected by the vigor of the plant but the measurements, and the tip/base angle ratio, indicate that the base angle is both absolutely and relatively narrower in weak plants as compared to vigorous plants. This indicates the importance of working only with vigorous plants where they are available. In attempting to identify a weak plant, it would seem best to rely principally on characters other than leaf base angle. Meader and Blake (5) found peach leaf base angles to be affected more than tip angles by the growth status of the plant. They suggest that only certain size classes of leaves, 5 to 6 inches or 6 to 7 inches, be used. Leaves of blueberry varieties vary in size so much that the establishment of size limits for criterion leaves would not be practical.

TABLE II—MEAN MEASUREMENTS AND RATIOS FOR TWO SEASONS AND TWO SOURCES OF LEAVES

Source	Adams	Grover	Harding	Rancocas	Rubel
Tip Angle					
N. J. 1940*	60.7 ±0.6‡	74.7 ±1.2	59.5 ±1.1	72.8 ±0.5	68.9 ±0.5
N. J. 1941**	59.6 ±0.4	73.6 +0.7	57.9 ±0.6	70.8 ±0.7	66.1 ±0.4
Mass. 1941†	60.0 ±0.7	81.9 ±0.5	62.9 ±0.6	76.1 ±1.0	69.6 ±0.6
Base Angle					
N. J. 1940	86.9 ±0.7	77.5 ±1.3	79.8 ±1.8	82.4 ±0.4	76.7 ±0.7
N. J. 1941	81.7 ±0.5	69.2 ±1.2	75.1 ±0.8	81.9 ±0.8	71.8 ±0.5
Mass. 1941	78.5 ±1.0	75.5 ±2.1	79.6 ±1.4	84.7 ±0.7	74.7 ±0.7
Tip/Base Angle Ratio					
N. J. 1940	0.699 ±0.008	0.956 ±0.013	0.750 ±0.024	0.886 ±0.069	0.905 ±0.010
N. J. 1941	0.713 ±0.004	1.073 ±0.014	0.769 ±0.017	0.876 ±0.008	0.916 ±0.008
Mass. 1941	0.766 ±0.012	1.084 ±0.012	0.795 ±0.020	0.900 ±0.013	0.933 ±0.009
Width/Length Ratio					
N. J. 1940	0.487 ±0.003	0.510 ±0.010	0.424 ±0.009	0.517 ±0.003	0.482 ±0.003
N. J. 1941	0.448 ±0.004	0.470 ±0.005	0.406 ±0.004	0.512 ±0.002	0.453 ±0.006
Mass. 1941	0.463 ±0.007	0.497 ±0.008	0.441 ±0.006	0.526 ±0.006	0.466 ±0.004

*10 selected leaves for first three varieties; Rancocas and Rubel based on 50 leaves per sample.

**30 leaves from 10 twigs, group 4–5–6.

†10 selected leaves.

‡Standard error of the mean

SUMMARY

Variability within blueberry leaf groups located on different parts of the twig was studied. On the basis of data presented leaves 4–5–6 from the tip of lateral branches 8 to 12 inches long exhibit a minimum of variability and hence are suggested as criterion leaves for leaf measurements to be made for the purpose of varietal identification. Measurements of certain varieties for two years and from two sources indicate that tip angle, base angle, and leaf width/length ratio are valuable and relatively constant variety characters. On weak plants, however, the data indicate that the base angle tends to be both absolutely and relatively narrower than on vigorous plants.

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Observations on the Inheritance of Horticulturally Important Characteristics in the Highbush Blueberry[1]

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AS a part of the blueberry breeding program of the South Haven Experiment Station, a record was made in 1937 of the inheritance of certain horticulturally important characteristics in 5,259 crossbred seedlings resulting from the use of a number of standard highbush blueberry varieties as parents. These plants were in their third year and bearing their first full crop. Growing conditions in 1937 were excellent and no adverse climatic conditions affected the crop.

It is realized that blueberry varieties are undoubtedly heterozygous for a great many genes, and that the characters considered are, for the most part, quantitative in nature, and therefore quite likely to be determined by multiple factors rather than single gene differences. With only a single generation of hybrids, it is therefore impossible to state with certainty the precise genetic behavior of each character. However, it is possible to show that in certain crosses, one or more characters predominate in the progeny. Comparatively little is known about inheritance in the blueberry and, until more detailed information is available, the knowledge of the capacity of a variety to transmit a certain trait should be helpful in the blueberry breeding program.

The results of this investigation are given in Table I. The varieties used were Adams, Rubel, Pioneer, Harding and Cabot. In each cross, only the percentage of seedlings inheriting the most desirable character is given. The individual bush and fruit characters and their behavior are considered separately, together with whatever conclusions may be drawn from the data.

BUSH CHARACTERS

An ideal highbush blueberry, from a horticultural point of view, should be upright in growth, of large size, and productive.

Habit of Growth:—Adams and Rubel are upright growing types. Pioneer is semi-spreading, and Harding and Cabot are spreading. Neither the upright nor the spreading habit is dominant. When Adams and Rubel, both upright, were crossed, over 50 per cent of the resulting seedlings were upright, 40 per cent semi-spreading, and 10 per cent spreading. A low percentage of upright seedlings resulted from the Harding x Cabot cross, these two varieties having a spreading habit. A variable percentage of upright progeny resulted from crossing a spreading with an upright variety, ranging from 27 to 56 per cent, allowing one to draw no definite conclusions as to the inheritance of growth habit. There are, undoubtedly many genes involved.

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Size of Bush:—Adams and Rubel produce large upright bushes, while Pioneer, Cabot and Harding bushes are smaller, in the order named, and generally spreading. Data concerning bush size is the least informative of all that gathered in this work. Crosses involving the smaller varieties produced as many large progeny as did the Adams x Rubel cross. However, the lowest percentages of large seedlings were found when Pioneer and Cabot were selfed, indicating that intervarietal crosses give evidence of hybrid vigor. This is further supported by the Cabot x Harding cross which yielded 69 per cent large seedlings even though the parental plants are both comparatively small.

Productiveness:—The standard blueberry varieties, barring frost and unfavorable growing conditions, are productive; often too much so. Pioneer, Cabot and Harding have a tendency to set more fruit than the plant can mature properly unless the bushes are carefully pruned. Rubel has the best balance between fruit set and foliage development with Adams a close second. Since the commercial varieties have been selected for productiveness, it is to be expected that they carry numerous factors favoring fruit set and yield. This is reflected in the data since crosses between extremely productive varieties resulted in a high percentage of seedlings of like habit.

FRUIT CHARACTERS

The ideal blueberry fruit will depend somewhat upon individual preference. In general, however, a large, firm, light blue berry of sweet flavor is the most desirable. Ease of picking is essential, and time of ripening is of importance.

Size of Berry:—Cultivated blueberries are commonly graded commercially by determining the number of berries required to fill a measuring cup. In Michigan, the Superior grade cannot have more than 90 berries in a cup; Golden Moon grade, 91 to 140; Columbia grade, 141 to 190; and the Lake State grade includes all berries over 190 per cup. Because of the large number of seedlings in this project, it was impossible to determine the size of berry by the number required to fill a measuring cup. Instead, it was necessary to use the terms, large, medium and small — large meaning berries approximately in the Superior and Golden Moon grades, medium in the Columbia grade, and small in the Lake State grade.

Of the varieties used as parents, Pioneer and Cabot, if properly pruned and fertilized, produce the largest berries. Rubel and Harding produce a medium-sized berry, while the Adams berry is medium to small. Aside from the Pioneer x Cabot and Cabot (selfed) progeny having a high percentage bearing large berries, the results were variable in the inheritance of this factor, although the percentages in most instances were quite low. Harding in particular showed a decided inability to transmit large berry size.

Color of Berry:—Blueberries vary in color from blue to black, with the lighter shades of blue being most popular on the market. Rubel and Cabot produce berries light blue in color, Pioneer medium blue, and Adams and Harding dark, the latter being nearly black. Rubel and

TABLE I—PERCENTAGE OF CROSSBRED SEEDLINGS OF STANDARD HIGHBUSH BLUEBERRY VARIETIES INHERITING MOST DESIRABLE CHARACTERS

Cross	Number Seedlings	Bush Characters			Fruit Characters					Average Date of First Ripening (August)
		Upright Growth	Large Size	Productive	Large Size	Blue Color	Firm Texture	Sweet Flavor	Easy to Pick	
Adams ×Cabot	681	47	44	61	22	76	10	9	94	7
Adams ×Pioneer	601	27	37	68	20	74	18	16	96	4
Adams ×Rubel	629	52	58	82	14	85	31	6	97	8
Cabot ×Harding	80	26	69	61	7	84	0	3	54	13
Cabot ×Pioneer	50	28	40	58	27	96	16	11	71	11
Cabot ×Rubel	165	41	73	79	17	91	17	4	90	12
Cabot (Selfed)	19	11	21	42	40	100	27	20	93	11
Harding ×Cabot	51	35	51	75	2	69	2	13	56	12
Harding ×Pioneer	110	18	44	83	8	63	8	18	100	12
Harding ×Rubel	146	49	56	69	15	77	21	15	90	12
Pioneer ×Adams	36	56	69	67	27	85	9	3	91	11
Pioneer ×Cabot	36	27	53	59	52	90	26	7	87	11
Pioneer ×Harding	160	24	71	98	21	76	4	32	93	11
Pioneer ×Rubel	300	35	70	94	15	97	51	21	92	14
Pioneer (selfed)	50	22	24	62	9	93	16	11	75	11
Rubel ×Adams	246	52	60	49	18	83	29	10	92	12
Rubel ×Cabot	115	48	67	75	26	85	20	7	92	11
Rubel ×Harding	725	27	46	74	21	61	27	19	92	14
Rubel ×Pioneer	929	27	45	56	23	96	62	27	95	11
Rubel (selfed)	130	43	47	59	25	97	53	13	99	18
Total No. Seedlings	5,259									

*Percentages are expressed to nearest full number.

Cabot must be homozygous, or very nearly so for factors governing light blue color, since on selfing 97 and 100 per cent of the progeny, respectively, were of like color. Light blue color, however, apparently was readily transmitted in any combination, although when the darker-berried parents (Adams and Harding) were used with other varieties there was an appreciable increase in number of plants producing the darker shades of berries.

Firmness of Berry:—Firmness is a necessary condition if the berries are to be shipped moderately long distances. Rubel and Pioneer produce very firm berries that ship well, Adams produces berries medium in firmness, while Cabot and Harding produce soft berries. Cabot x Harding seedlings all produced soft berries, while 62 per cent of the Rubel x Pioneer seedlings produced firm berries. The Pioneer x Rubel cross likewise gave a high percentage of firm-berried progeny, but Pioneer selfed yielded only 16 per cent. The effectiveness of transmission of firmness in the Pioneer-Rubel crosses apparently depended to a large extent on the Rubel parent, whether used as male or female. This is also evident from the fact that both Adams and Harding yielded low percentages of firm berries in all crosses except those involving Rubel.

Flavor:—Blueberries of different varieties are sweet, neutral, or sour in flavor, with the greatest percentage being neutral. Pioneer and Harding produce sweet berries. Cabot berries are mild to neutral, Adams neutral, and Rubel slightly sour unless fully ripe. In all of the crosses the percentage of sweet flavored berries was low, with the majority of the seedlings producing neutral berries. Pioneer and Harding, as might be expected, were most successful in transmitting sweet flavor to their progeny.

Ease of Picking:—The fruit can be picked from some varieties, such as Rubel, with ease, and a small, well-healed scar is left on the fruit at the point of attachment with the stem. Fruit of certain other varieties, such as Katharine, is picked with such difficulty that the stem pulls a portion of the flesh from the berry. Other varieties are intermediate in this respect. Pickers dislike to harvest varieties that adhere too tightly, and large scar injuries reduce the ability of the berries to withstand shipment.

Ease of picking is a dominant characteristic, judged from the high percentage having this characteristic in the progeny from all crosses. Reciprocal crosses between Harding and Cabot had by far the largest number of seedlings whose fruit adhered strongly to the stem.

Average Date of First Ripening:—The time at which a blueberry variety ripens is very important. In some parts of the United States, North Carolina for example, early maturing varieties are most valuable. In Michigan, late maturing varieties meet with the least competition on the markets and bring the best returns.

Of the varieties used, Cabot matures first, followed closely by Adams. Pioneer and Harding ripen in midseason, although they have very long seasons of maturity. Rubel begins to ripen about a week after Pioneer. A study of the average maturity dates of the seedlings from different crosses indicates that the female parent affects the time of maturity of the progeny more than does the male parent. Adams, when used as the maternal parent, consistently produced seedlings maturing early. Rubel influenced the ripening season toward lateness more than any other variety.

EVALUATION OF VARIETIES AS PARENTS

In Table II are listed the various crosses from which selections of merit were made and the number of selections in each cross.

TABLE II—THE RATING OF VARIOUS CROSSES BETWEEN HIGHBUSH BLUEBERRY VARIETIES ON THE BASIS OF THE NUMBER OF PROMISING SELECTIONS MADE

Cross	Total Number Seedlings	Number of Selected Seedlings
Pioneer ×Rubel	300	34
Rubel ×Pioneer	920	14
Adams ×Pioneer	601	12
Adams ×Cabot	681	8
Rubel ×Adams	246	5
Rubel ×Harding	725	4
Rubel ×Cabot	115	4
Adams ×Rubel	629	3
Pioneer ×Harding	160	2
Pioneer ×Cabot	36	1
Rubel (selfed)	130	1

Pioneer x Rubel provided the largest number of promising progeny, with the reciprocal cross next. The seedlings from these crosses have generally stood the test of time much better than those in the other crosses. Nearly all of the other selections have been discarded since

1937, although the two from the Pioneer x Harding cross have been retained because of late maturity and excellent flavor, despite only fair bush characters.

Following is a list of varieties which, on the basis of this experiment, best transmit certain horticulturally desirable characteristics.

Upright growth habit—Rubel, Adams.
Large bush size—Pioneer, Rubel.
High productiveness—All varieties used.
Large berry size—Results variable, Pioneer best.
Light blue color—Rubel, Cabot.
Firm berry—Rubel.
Sweet flavor—Pioneer, Harding.
Ease of picking—All varieties used.
Early ripening—Adams.
Late ripening—Rubel.

Some Plant-Spacing Results With Six Strawberry Varieties[1]

By W. H. CHILDS, *West Virginia Agricultural Experiment Station, Morgantown, W. Va.*

SINCE Darrow and Dearing (1) first reported the results of spacing Blakemore strawberry plants in North Carolina, other investigators have studied different phases of spacing work to determine the most desirable distance for several varieties under a wide range of soil and climatic conditions, and to explain the results obtained. This paper, which adds to the data already available for a few varieties, also gives results with some varieties not hitherto studied, and considers certain phases not previously emphasized.

Two 94-foot rows of each of six varieties, Blakemore, Catskill, Culver, Fairfax, Gandy, and Premier, were set out at Morgantown, West Virginia, on March 30, 1937. The soil is a Tilsit silty clay loam, which is considered to be one of the poorer soil series in West Virginia. A moderate dressing of manure, together with superphosphate and muriate of potash at 300 pounds and 100 pounds per acre, respectively, was worked in while preparing the soil, and the plants were top-dressed with nitrate of soda at the rate of 125 pounds per acre 3 weeks after they were set and again on August 15.

All plants were set 3½ by 1½ feet, and one row of each variety was permitted to form a 24-inch matted row. Each parent plant in the other row was allowed to form nine runner plants, these being evenly distributed through a 24-inch row to give an average of 3⅓ plants per square foot, or a spacing of approximately 8 inches between plants. The runners were accurately placed so that the spacing was uniform, and a full stand was obtained by late July. All subsequent runners were removed at frequent intervals.

A mulch of rye straw was applied in December and removed on April 10, 1938. A hard frost on May 12 killed an estimated 25 per cent or more of the bloom, varying with the variety. Other than that, the season was favorable to good production since the rainfall for May was 3.06 inches above normal and that for June was 1.54 inches above normal. Before harvesting was begun, three 25-foot blocks were selected in each row, care being taken that a border was left at each end of the row and that there were no vacancies in any block. Corresponding blocks in the matted row and spaced row stood side by side and were paired for comparison by Student's Method. Yields in grams were kept for each block, and a count of the number of berries in 2,000 grams or in the complete picking if it were less than 2,000 grams, was taken for each treatment at each picking.

After harvest in 1938, the matted row for each variety was renovated by removing an 8-inch strip of plants from each side of the row and thinning the remaining plants to stand approximately 8 inches apart. A new matted row was formed by late summer. The spaced row was permitted to remain intact, and all runners were removed at frequent intervals. The author was on leave of absence in 1939, and the records kept for that harvest season were by the full row rather than by smaller blocks. No notes were taken as to the per cent stand in each row, so no great emphasis can be placed on the differences obtained.

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[1] Published with the approval of the director of the West Virginia Agricultural Experiment Station as Scientific Paper No. 275.

RESULTS AND DISCUSSION

Tables I and II summarize the data obtained in 1938. Spacing increased the yield in all cases excepting for the Gandy variety. Observation indicated that the reason for the decreased yield in this case was that there was not proportionately as great an increase in plant size when the excess runners were kept off as with the other varieties.

TABLE I—YIELD OF STRAWBERRIES IN 1938 AS INFLUENCED BY PLANT SPACING

Treatment	Actual Yield (Grams Per 25 Foot Block)			Yield Calculated (Quarts Per Acre)				Per Cent Increase for Spacing	Odds in Favor of Spacing
	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Average		
Premier									
Matted row......	9435	9207	10937	7700	7514	8926	8047	24.7	70:1
8-inch spacing ...	11822	12391	12684	9648	10112	10352	10037	—	—
Blakemore									
Matted row.. ..	5711	5149	4402	4661	4202	3593	4152	45.9	109:1
8-inch spacing ...	8606	6999	6661	7023	5712	5436	6057	—	—
Catskill									
Matted row. . .	7435	8555	7195	6068	6982	5872	6307	29.2	>400:1
8-inch spacing. ..	9536	10808	9613	7782	8821	7845	8149	—	—
Fairfax									
Matted row......	5086	5037	4546	4151	4111	3710	3991	47.5	66:1
8-inch spacing ...	7793	7861	5990	6360	6415	4889	5888	—	—
Culver									
Matted row	6109	4864	4858	4986	3970	3965	4307	41.5	19:1
8-inch spacing .	6837	7591	7971	5580	6195	6505	6093	—	—
Gandy									
Matted row......	4478	4558	3902	3655	3720	3184	3520	-32.4	22:1*
8-inch spacing ..	3928	2523	2290	3206	2059	1869	2378	—	—

*In favor of matted row.

For the other five varieties, the percentage increase in yield ranged from 24.7 per cent in the case of Premier to 47.5 per cent in the case of Fairfax. These increases were distinctly significant for all the varieties excepting Culver, which showed odds of 19 to 1 in favor of spacing. Since the increase in berry size, as given in Table II, was only great enough to account for as much as half of the yield increase for but one of the five varieties, it is evident that the greater number of berries obtained under the spacing treatment was the more important factor. Berry size was increased in all cases by spacing, however.

The data for 1939 are summarized in Table III. Although no great importance can be given to the differences shown for the reasons

TABLE II—THE INFLUENCE OF STRAWBERRY PLANT SPACING ON BERRY SIZE AND DISTRIBUTION OF YIELD IN 1938

Yield	Treatment	Yield Distribution			Size as Shown by Average Number Berries Per 2000 Grams*
		Pickings 1 to 4	Pickings 5 to 7	Pickings 8 to 10	
Premier					
Yield (grams)	Matted row	17,335	8,704	3,540	375
	8-inch spacing	14,308	14,974	7,615	333
Per cent of total yield	Matted row	58.61	29.42	11.97	—
	8-inch spacing	38.77	40.59	20.64	—
Blakemore					
Yield (grams)	Matted row	3,878	7,802	3,582	508
	8-inch spacing	13,506	7,891	869	400
Per cent of total yield	Matted row	25.41	51.12	23.47	—
	8-inch spacing	60.65	35.44	3.91	—
Catskill					
Yield (grams)	Matted row	7,858	8,416	6,911	352
	8-inch spacing	19,156	5,949	4,851	295
Per cent of total yield	Matted row	33.90	36.30	29.81	—
	8-inch spacing	63.95	19.86	16.20	—
Fairfax					
Yield (grams)	Matted row	2,496	6,636	5,537	484
	8-inch spacing	3,465	9,847	8,332	447
Per cent of total yield	Matted row	17.01	45.24	37.74	—
	8-inch spacing	16.00	45.50	38.50	—
Culver					
Yield (grams)	Matted row	9,145	4,297	2,389	370
	8-inch spacing	11,397	8,040	2,962	299
Per cent of total yield	Matted row	57.77	27.13	15.09	—
	8-inch spacing	50.88	35.89	13.22	—
Gandy					
Yield (grams)	Matted row	911	5,899	6,128	528
	8-inch spacing	2,383	4,636	1,722	444
Per cent of total yield	Matted row	7.04	45.59	47.37	—
	8-inch spacing	27.27	53.04	19.71	—

*A weighted average based on count in 2000 grams for each treatment at each picking.

already mentioned, it is noteworthy that the spaced row outyielded the matted row in every case.

The effect of plant-spacing on distribution of yield differed somewhat in 1938 for the varieties studied. When the plants were spaced, a much higher percentage of the total yield was obtained in the early part of the picking season for Blakemore, Catskill, and Gandy, while little influence was noted with Fairfax or Culver. Premier was the only variety for which the matted-row treatment was earlier, and even

TABLE III—YIELD OF STRAWBERRIES IN 1939 AS INFLUENCED BY PLANT SPACING (QUARTS PER ACRE)

Variety	Premier	Blakemore	Catskill	Fairfax	Culver	Gandy
Matted row	7128	6040	4907	3764	3854	3064
8-inch spacing	7490	8818	9897	6395	4923	4286
Per cent increase for spaced row	5.3	46.0	101.7	69.9	27.7	35.6

with this variety the actual yields were but slightly less in the early part of the season for the spaced row. For all the varieties excepting Premier, the actual yields were greater in the early part of the season, being much greater for Blakemore, Catskill, and Gandy. Whether or not the frost damage noted above influenced yield distribution cannot be definitely stated, but there appeared to be no appreciable difference in the amount of injury to the plants of the spaced row as compared with those of the matted row of a given variety.

In 1939 the spaced row was distinctly earlier than the matted row for all varieties. Since there were no late killing frosts that spring, it is possible that the yield distribution was more typical than in 1938.

SUMMARY

In a strawberry plant-spacing study at Morgantown, West Virginia, from 1937 to 1939, inclusive, plants spaced 8 inches apart outyielded the matted row for Blakemore, Catskill, Culver, Fairfax, and Premier, but not for Gandy. These increases were of considerable magnitude in most instances. Both a greater number of berries and an increased size of berry were noted in the spaced row, but the former was somewhat more important in influencing yield. In general, production was earlier when the plants were spaced, although this did not hold true for all varieties in 1938.

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Experimental "Smothering" of Dormant Strawberry Plants[1]

By W. G. Brierley and R. H. Landon, *University of Minnesota, St. Paul, Minn.*

THE results of previous investigations relating to the winter behavior of strawberry plants have indicated that the respiratory rate of dormant plants is relatively low during the winter months (2), and that an ice seal maintained for 10 weeks or longer is not likely to cause serious injury (3). Attempts to measure the respiratory activity and possible "smothering" of dormant plants sealed in ice proved unsatisfactory (3). This was due partly to the great care required in maintaining a tight seal, and partly to injury that apparently was caused by an unavoidable excess of water during thawing, as well as other difficulties. These experimental procedures indicated, however, that dormant strawberry plants are not readily "smothered".

Experimental Procedure

In order to avoid the difficulties encountered when an ice seal was used, tightly sealed glass jars were used as containers in the 1938–39 experiments. Heavy glass jars of approximately 2-liter capacity were sealed with tight-fitting rubber stoppers through which two glass tubes had been inserted. Pieces of heavy rubber tubing about a foot long were slipped over the outer ends of the glass tubes. The ends of the rubber tubing were folded back and compressed with screw clamps. This arrangement facilitated withdrawal of samples of the confined air for analysis. A Fisher portable gas analyser was used. The burette of this apparatus has a capacity of 100 cubic centimeters with a scale divided into tenths of a cubic centimeter. Oxygen was absorbed by a solution composed of 1 part pyrogallol, 5 parts sodium hydroxide, and 30 parts of water. Carbon dioxide was absorbed by a 20 per cent sodium hydroxide solution.

The plants used were taken from winter storage and selected for uniformity in size and condition. Lots of a like number of plants were weighed and placed carefully in the jars. The jars then were sealed and placed in storage at —3 degrees C.

Results of the preliminary study conducted in the winter of 1938–39 have been reported previously (3) but are repeated here in order that all the data obtained in this study may be included. The data obtained in the preliminary study conducted during 1938–39 are shown in Table I. This table shows clearly the rapid increase in the concentration of CO_2 and the decrease in O_2 during the 2 weeks period. Because the atmospheric oxygen was almost completely exhausted it appeared desirable to end the study after 2 weeks in order to note the condition of the plants. Examination of the crowns of 20 plants from each jar

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TABLE I—Concentration of Carbon Dioxide and Oxygen Produced in Sealed Glass Jars by Dormant Strawberry Plants 1938–39 (Variety Beaver, 50 Plants per Jar, Stored at —3 Degrees C)

Jar No.	Weight of Plants (Grams)	First Week		Second Week	
		CO_2 (Per Cent)	O_2 (Per Cent)	CO_2 (Per Cent)	O_2 (Per Cent)
1	361	13.8	2.6	20.3	0.7
2	387	11.0	4.5	20.0	0.1
3	378	13.0	5.4	19.1	0.3

showed little injury of a serious nature and the remaining 30 plants from each jar grew normally after they were thawed over night at 5 degrees C, potted, and moved gradually into a warm greenhouse.

As no serious injury was observed in the preliminary test a larger number of samples were prepared in 1939–40 and the study carried on for 7 weeks. Winter stored plants of the Beaver variety were used. As slightly smaller jars were used the number of plants per lot was reduced to 40. The plants were selected for uniformity in size and condition, and were weighed before they were placed in the jars. After the jars were sealed they were placed in storage at —3 degrees C. Analyses of the confined air were made at weekly intervals for all the jars. At the end of the second week, and at weekly intervals thereafter, two jars were opened. The crowns of 15 plants from each jar were sectioned to note the extent of discoloration. The remaining 25 plants were thawed over night at 5 degrees C. They then were potted, held in a cool greenhouse for a week, and finally placed on a greenhouse bench at 25 degrees C where their growth behavior could be observed.

The extent of browning, except in lot 1, was not serious. Although there was some variation in the condition of the plants from the several jars, all compared favorably with checks taken directly from winter storage. When lots 3 and 4 were opened at the end of the third week a slight fermented odor was noticed. This odor was more pronounced in later lots, but appeared to have no definite relation to the condition of the plants or to their subsequent growth behavior.

The data obtained in 1939–40 are shown in Table II. This table shows the length of time each lot was sealed, the percentage of CO_2 and O_2 found in the final analyses, and the subsequent growth behavior of 25 plants from each lot after 3 weeks on the greenhouse bench.

As the study progressed the percentage of CO_2 showed variations between lots, but in general there was a sharp rise during the first week followed by a gradual increase from week to week with a maximum of 27.7 per cent in lot 7. The percentage of O_2 declined sharply during the first 2 weeks. In lots 2 and 4 no measurable amount could be detected at the end of 2 and 3 weeks respectively. All other analyses showed O_2 to be at very low levels.

This table also shows that, except for lot 1, the subsequent growth of the plants was satisfactory. Few losses were noted and the plants generally were growing about as vigorously as those in the check lot

TABLE II—CONCENTRATION OF CARBON DIOXIDE AND OXYGEN PRODUCED IN SEALED GLASS JARS BY DORMANT STRAWBERRY PLANTS, AND GROWTH BEHAVIOR AFTER 3 WEEKS IN THE GREENHOUSE 1939–40 (VARIETY BEAVER, 40 PLANTS PER JAR, STORAGE TEMPERATURES —3 DEGREES C, ANALYSES AT WEEKLY INTERVALS)

Lot No.	Weight of Samples (Grams)	Sealed in Jars (Weeks)	Final Analyses of Confined Air		Growth Behavior After 3 Weeks in Greenhouse (25 Plants Per Lot)		
			CO_2 (Per Cent)	O_2 (Per Cent)	Vigorous (No.)	Weak (No.)	Dead (No.)
1	264	2	26.0	0.4	14	1	10
2	239	2	19.1	0.0	24	1	0
3	223	3	23.9	0.1	24	0	1
4	233	3	24.5	0.0	22	2	1
5	236	4	27.3	0.5	20	2	3
6	223	4	25.7	1.8	23	2	0
7	230	5	27.7	0.2	23	1	1
8	249	5	21.8	1.0	24	0	1
9	229	6	21.2	0.4	24	0	1
10	236	6	17.7	0.7	25	0	0
11	229	7	18.5	1.2	25	0	0
12	230	7	24.8	0.6	24	1	0
Check plants from winter storage					25	0	0

after 3 weeks on the greenhouse bench.

The poorer performance of lot 1 apparently was due to an unintentional variation in the temperature treatment. As somewhat smaller jars were used than in 1938–39 this jar was prepared 3 days before the others in order to determine the number of plants to be used. When filled with plants it was stoppered but not sealed and held in storage at +2 degrees C for 3 days. The noticeably heavy loss of plants apparently was due to this short exposure to a temperature only slightly above freezing. In 1 week after the jar was sealed the concentration of CO_2 had risen to 24.5 per cent and that of O_2 had fallen to 0.3 per cent. When the jar was opened at the end of the second week a strong fermented odor was noticed. The loss of 10 plants in the subsequent growth test also was greatly in excess of the losses that occurred in the other lots. This behavior, in agreement with the observed losses of the plants in winter storage at temperatures slightly above freezing (1), suggests the possibility that temperatures only a few degrees above freezing may cause more serious injury to plants kept closely confined than has been observed in earlier studies with plants sealed in ice and held at a moderate temperature below freezing.

As growth of the plants in the other lots showed no serious injury, or indication of "smothering", the technic was examined critically to note if the procedure was faulty. The volume of air confined within the jars, after the space occupied by the plants was deducted, was found to average 1,120 cubic centimeters. In the analytic procedure 25 cubic centimeters of the confined air was used to sweep the tubing and connections and then 100 cubic centimeters was withdrawn for analysis. As this total of 125 cubic centimeters of the confined air was withdrawn a like volume of fresh air, which contains approximately 20 per cent O_2, was drawn into the jars. In relation to the volume of air within the jars this resulted in the addition of between 2 and 2.25

per cent of O_2 to each jar each week. Although this percentage is relatively very low, and much of it appeared to be used during the ensuing week, apparently it was sufficient to meet the requirements of the confined dormant plants. This test did not demonstrate "smothering" but it did show clearly that dormant strawberry plants left closely confined at a temperature slightly below freezing require very little oxygen to maintain life. The test also showed that the confined plants were able to survive and grow normally after being exposed for several weeks to a high concentration of CO_2

As it was evident that more severe treatment would be required to cause "smothering" the study was repeated in 1940–41. As suitable plants of the Beaver variety were not available, vigorous plants of the Premier variety were used. These plants were larger than those previously used so only 25 could be placed in each jar. The principal change in procedure was that the analyses of the confined air in the jars were made only at the time the lots were withdrawn for thawing and potting. In this way no oxygen was admitted to the jars after they were sealed, and the plants were limited to the oxygen in the air within the jars though anaerobic respiration may have played a role in the survival of the confined plants.

The results of this study are shown in Table III. This table shows that there was the same general tendency for the concentration of CO_2 to increase during the period of 7 weeks, but the percentages toward the end of the study were much higher than any previously recorded. The high concentration of 44.7 per cent was found in lot 11 after 7 weeks. Oxygen was found to be at very low levels, but in no case was it entirely absent. The fermented odor observed previously was again detected as the jars were opened. It was very pronounced in lots 11 and 12.

TABLE III—Concentration of Carbon Dioxide and Oxygen Produced in Sealed Glass Jars by Dormant Strawberry Plants, and Growth Behavior After 2 Weeks in the Greenhouse 1940–41 (Variety Premier, 25 Plants per Jar, Storage Temperature —3 Degrees C, Analyses Only at Time of Withdrawal)

Lot No.	Weight of Samples	Sealed in Jars	Analyses of Confined Air		Growth Behavior After 2 Weeks in Greenhouse (25 Plants Per Lot)		
	(Grams)	(Weeks)	CO_2 (Per Cent)	O_2 (Per Cent)	Vigorous (No.)	Weak (No.)	Dead (No.)
1	396	2	19.5	1.0	25	0	0
2	335	2	20.7	—	23	2	0
3	325	3	19.3	0.3	24	1	0
4	369	3	24.0	0.2	25	0	0
5	386	4	31.0	0.6	24	1	0
6	326	4	24.2	0.4	23	2	0
7	377	5	27.2	1.4	19	6	0
8	358	5	(1)*	(1)*	—	—	—
9	369	6	42.5	0.3	0	21	4
10	366	6	29.6	0.8	0	12	13
11	450	7	44.7	0.7	0	0	25
12	354	7	40.2	0.3	0	0	25
Check plants from winter storage					25	0	0

*1 Leakage.

The plants in all the jars appeared to be in good condition when removed for thawing and potting. The old foliage was of a normal green color and there were no indications of injury. In the first six lots new leaves developed rapidly, and their color and form were normal. The old leaves gradually turned brown and died. Indications of injury were noted in the plants from lots 9 and 10 after they had been thawed over night at 5 degrees C. Some of the tightly folded new leaves at the tips of the crowns were dark in color and a few of the crowns were soft and watery. The plants from lots 11 and 12 were markedly discolored after thawing over night and all were in poor condition.

The growth behavior of the plants in the first six lots, covering a period of 4 weeks in the sealed jars, was in general as good as that of the lots observed in the previous year, (Table II). As growth of equal vigor in the field would be considered excellent it was apparent that no "smothering" had occurred after 4 weeks under the severe conditions of the test.

The first indication of injury during the subsequent growth test was observed in lot 7 which had been sealed for 5 weeks. Growth of the plants in this lot was retarded in comparison with that of the earlier lots. The plants were somewhat stunted and abnormal in appearance. The first new leaves were etiolated and were more or less scorched at the margins. In leaves that developed later the margins were curled downward at first, but recovered with further development. After 2 weeks in the greenhouse the plants rated as either vigorous or weak were not quite comparable to those of similar ratings among the earlier lots. None of the plants were dead, however.

Growth of the plants in lots 9 and 10 was markedly retarded. Their appearance was similar to that of lot 7, but scorching of the new leaves was more general, and the old leaves turned brown and died within a day or two. After 2 weeks in the greenhouse none of these plants were vigorous and 13 of them were dead in lot 10.

Although the plants in lots 11 and 12 were of a normal green color when removed from the jars, they all turned brown when thawed over night at 5 degrees C and none showed any indications of life after 2 weeks in the greenhouse.

When it became apparent that the plants in lot 7 were injured, the study of the growth response of lots 5, 7 and 9 was continued to observe their later behavior. At the end of 4 weeks in the greenhouse 24 plants in lot 5 still were uniformly vigorous and were developing blossoms, but the 1 weak plant had died. The plants in lot 7 as a group declined in vigor so after 4 weeks only 12 were vigorous, 7 were weak, and 6 were dead. The living plants were ragged in appearance and only a few blossoms had appeared on the strongest plants. Some of the plants showed a peculiar partial development. The tips of the crowns appeared to be killed and the development of new leaves and branch crowns occurred irregularly below the tips. Of the 21 weak plants in lot 9, 2 gained slightly in vigor after 4 weeks, but 8 remained weak, 7 were very weak, and 4 had died. The tips of all the crowns were killed. The living plants generally developed only one to two new leaves on the sides of the crowns, but in one plant a weak branch crown appeared. Only one blossom bud developed.

At the end of 4 weeks in the greenhouse the crowns and roots of all the living plants in lots 5, 7 and 9 were examined to note the extent and type of injury. In lot 5 there was only a light browning of the medulla that commonly has been observed in field grown plants in the spring, and new rootlets had formed in abundance. An examination of the 12 vigorous plants in lot 7 revealed that all the crowns were dark brown at the base of the medulla. The roots were discolored and some were dead; but many new rootlets were developing and the plants apparently would have recovered ultimately. A peculiar form of injury was observed in the meristematic region at the base of the tips where the tissues were dark brown and collapsed. In the 7 weak plants these brown and collapsed areas were larger and darker in color and few new rootlets had developed. It was considered doubtful if any of these weak plants would have recovered. In lot 9 all the crowns were very dark brown and only a very few new rootlets had developed. The same type of injury was observed as in lot 7, but this injury was more pronounced.

CONCLUSION

From this evidence it is apparent that dormant strawberry plants may be "smothered" when tightly sealed in glass jars in the laboratory, although only nominal injury occurred during the first 4 weeks. Whether the injury and death at longer periods was due to lack of oxygen, or to the high concentration of carbon dioxide, has not been determined. In view of the results of earlier studies, and as ice in the field usually is granular, cracked, and more or less filled with straw and leaves, it seems doubtful that conditions in the field are likely to be so severe. Until further evidence is available, it would seem that losses of plants in the field are more likely to be due to other causes.

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Strawberry Plant Behavior as Influenced by Mulch (Preliminary Report)[1]

By W. D. Armstrong, *Kentucky Agricultural Experiment Station, Lexington, Ky.*

STRAWBERRY mulching studies, comparing time and amount of mulch applications, were carried out from the fall of 1938 through the spring of 1940 in commercial fields. Treatments were at the rate of none, 1, 2, and 3 tons of wheat straw per acre on different 1/80-acre plots. The times of application were mid-December, early February, and late March; the first and last dates representing wide commercial practice in western Kentucky. The winter of 1938–39 was unusually mild and open, followed by a moist, cool spring. Practically no winter injury occurred that year even on unmulched and lightly mulched plots. Heavy overwintering mulch reduced soil loss from erosion and heaving.

The winter of 1939–40 was one of the most severe on record, following an open, late fall. Mid-January saw temperatures of 6 to 12 degrees below zero through western Kentucky, with no snow on the ground. Even the heaviest mulch used was not heavy enough to prevent some winter injury. Unmulched and lightly mulched plots were severely winter injured, many smaller plants being killed. In the spring of 1940, many plants (especially Aroma)in unmulched or spring-mulched plots failed to blossom, but made vigorous growth. Such behavior in other years had been interpreted by growers as "running-out" of the variety. Early-mulched plots showed a large increase in yield over spring-mulched plots with Aroma showing the greatest increase. Blakemore plots, both early-mulched and late-mulched, showed a much greater 1940 yield than Aroma plots similarly treated. Second-year Blakemore plots with a thick stand of plants did not show an increase in yield in 1940 in favor of early mulching over spring mulching.

Heavy December and February mulching retarded blossoming and ripening dates both years. All mulches retarded weed and vegetation growth in plots, with 1 ton showing least effect. A moist spring in 1939 tended to equalize size of fruit on most plots. In 1940, fruit size was increased in heavy-mulched, second-year plots with a heavy mat of plants but not so in thin stands of 1-year plants. In all cases berries on the mulched plots were the cleanest and brightest. In 1940, many berries on the unmulched and late mulched plots had dead and bronzed "caps" while caps of berries on the early-mulched plots were bright and green.

Mulch treatments in this southern intermediate section seem to need considerable understanding and manipulation. Severely cold winters and cold spells occur so often that great benefit may be expected from the use of overwintering mulch in most years.

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[1] The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

The Influence of Various Renewal Systems and Width of Row on Yields of the Blakemore Strawberry[1]

By JULIAN C. CRANE and I. C. HAUT, *University of Maryland, College Park, Md.*

THE results of previous work (1) on the relationship of width of thinned row to productiveness in the Blakemore strawberry have shown that in the first fruiting year as the width of row decreased the yield per acre progressively increased. This paper presents the results of second-year studies on fruit production and plant growth from the same plots following three systems of renewal.

METHODS

Since the plot layout in this experiment has been previously reported (1), only a brief review will be presented. It consisted of three rows each of 10-inch, 20-inch, 30-inch, and 40-inch width of plants with a 10-inch alley between rows. There were five plot replications of each treatment, making a total of 15 rows for each of these widths. All plants in the various width rows were thinned to a distance of 4 to 6 inches between plants.

Following the fruiting period in 1940, three renewal systems were devised for second-year fruiting studies. Three-row plots in the original design made possible single row randomized renewal treatments with five plot replications for each renewal treatment under the four different widths of row. The three renewal systems are described as follows:

1. *Original Plants Fruited the Second Year:*—This method consisted of removing all runners every 2 weeks throughout the season of runner formation, thus retaining the same plants which fruited in 1940 for fruiting again in 1941. Reference to this method throughout the article will be designated as the "2-year plant renewal system".
2. *Conventional Method:*—The rows were "barred off" from each side leaving only a middle strip of plants 5 inches wide. From these plants runners were allowed to form and fill out the rows to the various widths desired. The plants in these rows were thinned by the method previously reported (1), to a distance of 4 to 6 inches between plants. This treatment was therefore a replication of the treatment given all of the rows in the experiment the previous year.
3. *Reversion to a Matted Row:*—This system was accomplished merely by allowing the original thinned rows to revert to matted rows of similar widths. This type of renewal therefore consisted, at harvest time, of rows containing the original or 2-year old plants interspersed with as many 1-year-old or new runner plants as took root within the designated widths of row.

A commercial fertilizer of 5–10–5 analysis was applied to all plots August 1, 1940 at the rate of 150 pounds per acre. A 6-inch layer of rye straw mulch was applied to the plots the middle of November and on April 1 it was raked into the aisles and excessive amounts removed.

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[1] Scientific Paper No. A 25, Contribution No. 1835 of the Maryland Agricultural Experiment Station.

Harvesting began May 19, 1941 and pickings were made approximately every other day until the season ended June 9. The berries were weighed, graded, and counted as in the previous year.

The crop was threatened by drought so a portable overhead Skinner irrigation system was set up and each plot given an amount of water equivalent to 6 acre-inches, approximately an inch every 3 days throughout the picking season.

RESULTS

The data presented in Table I clearly indicate that with thinned rows of Blakemore, the frequent removal of all runners, thereby fruiting only the original plants during the second year, results in much greater yields than can be obtained from either a conventional renewal practice of "barring off" the rows or by permitting the thinned rows to revert to a matted row condition. Increases in yield from this method approximated 66 and 81 per cent over the latter two methods respectively. Differences in yield between the former method and either of the latter two methods were highly significant as calculated by analysis of variance. The data further indicate that yields equal to those obtained by the conventional "barring off" may be obtained from thinned rows when allowed to revert to a matted row the second year.

TABLE I—INFLUENCE OF RENEWAL SYSTEM AND WIDTH OF ROW ON PRODUCTION OF THE BLAKEMORE STRAWBERRY WITH THE PERCENTAGE DEVIATION FROM THE CONVENTIONAL RENEWAL SYSTEM (CHECK) 1941 (YIELDS OF U. S. NO. 1 BERRIES, QUARTS PER ACRE BASIS)

Renewal System	Width of Row				Difference Necessary for Significance Between Renewal Systems*
	10-Inch	20-Inch	30-Inch	40-Inch	
Conventional renewal	6,910	5,923	5,399	5,397	5 per cent level
Per cent deviation	—	—	—	—	1,211 quarts
Matted row renewal	6,337	6,231	4,836	4,737	1 per cent level
Per cent deviation	−8.3	+5.2	−10.5	−12.3	1,621 quarts
Two-year plant renewal	11,476	9,435	8,720	7,099	—
Per cent deviation	+66.0	+59.2	+61.5	+31.5	—

*Difference necessary for significance between width of rows: 5 per cent 1,398 quarts; 1 per cent 1,872 quarts.

As the width of row decreased a progressive increase in yield per acre resulted regardless of the renewal system. This is consistent with the results obtained during the first year of fruiting. This is especially evident with the 2-year plant renewal system in which, without exception, the yields from the 10-inch width rows were highly significant over all other widths.

With the conventional renewal method there is no significant difference in yield between the 10- and 20-inch widths or between the 30- and 40-inch widths but yields from the 10-inch width rows are significantly greater at the 5 per cent level than the 30- and 40-inch widths. The same holds true for the matted row renewal; the yields of the 10-inch rows being significantly greater at the 5 per cent level than the 30- and 40-inch rows. The differences are not as great, however,

TABLE II—COMPARATIVE DECREASES FROM FIRST YEAR YIELDS OF VARIOUS SECOND-YEAR RENEWAL SYSTEMS UNDER DIFFERENT WIDTHS OF ROW (1941)

Renewal System	Width of Row				Average
	10-Inch (Per Cent)	20-Inch (Per Cent)	30-Inch (Per Cent)	40-Inch (Per Cent)	
Conventional renewal. . .	43.3	44.0	41.6	33.9	40.7
Matted row renewal . . .	48.0	41.1	47.7	42.0	44.7
Two-year plant renewal	5.7	10.8	5.7	13.1	8.8

as those obtained for the 2-year plant renewal system.

Table II gives data showing the comparative decreases from first-year yields of the various renewal systems under the different widths of row. The data show that the rows composed of 2-year plants yielded an average of only 8.8 per cent less during the second year of fruiting while the conventionally renewed and matted row systems produced an average of 40.7 and 44.7 per cent less respectively the second year. Variations in width of row under a particular renewal system seemed to have no marked effect on the percentage decrease in yield from the first year yields. There is some indication with the 2-year plant renewal system that the narrower rows tend to yield more the second year than do the wider rows. However, this is not true with the conventional or matted row renewals.

As soon as harvesting was completed, five separate square-foot random samples of plants were dug for each renewal system on each width of row. The roots were carefully washed and the plants were dried in an oven. The data in Table III show that the average dry weight per plant, under the 2-year plant renewal system, was 9.4 grams while with the conventional renewal method the average dry weight per plant was 5.7 grams. With all the runners removed from the 2-year plants, larger leaf areas, crowns, and root systems, as well as larger food reserves were built up. These factors are directly reflected in the larger yields obtained the second year on rows in which the original plants were fruited. In the matted rows, the 2-year plants averaged 5.9 grams per plant while the interspersed 1-year plants averaged 1.1 grams. The failure of the 2-year plants in the matted row system to develop and

TABLE III—INFLUENCE OF RENEWAL SYSTEM AND WIDTH OF ROW ON THE AVERAGE DRY WEIGHT (GRAMS) PER PLANT (AVERAGE OF PLANTS TAKEN FROM FIVE RANDOM SAMPLINGS OF ONE SQUARE FOOT EACH)

Renewal System	Width of Row				Average
	10-Inch	20-Inch	30-Inch	40-Inch	
Conventional renewal; 1-year thinned plants.	7.7	6.5	4.3	4.4	5.7
Matted row renewal:					
2-year plants.	7.7	5.5	5.7	4.6	5.9
1-year plants.	1.0	1.2	1.0	1.1	1.1
Two-year plant renewal.	10.1	9.0	8.9	9.7	9.4

attain the size of plants in the 2-year plant renewal system is indicated by the comparative average dry weights per plant of 5.9 and 9.4 grams respectively. The smaller size also indicates the adverse effect of new runner formation and increased competition for water and nutrients upon the development of these plants under matted row renewal during the second growing season. Moreover, these plants progressively decreased in average dry weight from 7.7 grams per plant in the 10-inch row to 4.6 grams per plant in the 40-inch row, indicating that competition also increased as width of row increased. This is likewise indicated by the data presented for the thinned plants in the conventional renewal system where a decrease from 7.7 grams per plant in the 10-inch row to 4.4 grams per plant in the 40-inch row occurred. A comparison of the very low average dry weight of 1.1 grams per runner plant from the unthinned matted row renewal system with the average dry weight of 5.7 grams per plant for those in the thinned conventional renewal system again illustrates the effect of excessive competition upon the plant development of Blakemore.

The data in Table IV show that the percentage of U. S. No. 1 berries of the total yield did not vary greatly on rows of different widths. However, there was a difference among renewal systems in that the matted row system produced approximately 13 per cent fewer marketable berries of the total yield than did the other two renewal systems. Relative to size of U. S. No. 1 berries as shown by the number of berries per quart, the 2-year plants produced berries slightly larger than those from the conventional renewal system while the berries from the matted rows were considerably smaller.

TABLE IV—PERCENTAGE OF U. S. NO. 1 BERRIES OF THE TOTAL YIELD, NUMBER OF U. S. NO. 1 BERRIES PER QUART, AND THE PERCENTAGE YIELD DECREASE OF OTHER WIDTHS AS COMPARED TO THE 10-INCH WIDTH (1941)

Yield	Width of Row				Average
	10-Inch	20-Inch	30-Inch	40-Inch	
Conventional Renewal					
U. S. No. 1's, percentage of total yield	77	77	79	80	78.2
No. U. S. 1's per quart	120	116	118	115	117
Yield decrease compared to 10-inch row (per cent)	—	14	22	22	——
Matted Row Renewal					
U. S. No. 1's, percentage of total yield	66	67	62	64	64.7
No. U. S. 1's per quart	126	124	127	125	125
Yield decrease compared to 10-inch row (per cent)	—	2	24	25	——
Two-Year Plant Renewal					
U. S. No. 1's, percentage of total yield	78	77	77	78	77.5
No. U. S. 1's per quart	112	116	115	117	115
Yield decrease compared to 10-inch row (per cent)	—	18	24	38	——
Percentage yield decrease compared to 10-inch row in first year (1940) fruiting	—	13	24	33	——

The data in Table IV, comparing yields on a percentage basis, further show that, as the width of row decreases, the yield per acre increases. Thus, with the 2-year plant renewal system, progressive decreases from the 10-inch width rows of 18, 24, and 38 per cent occurred for the 20-, 30-, and 40-inch widths respectively. While these differences are not so great for the other two renewal systems, significantly greater yields were obtained on the narrower width rows regardless of the renewal system employed.

SUMMARY

With Blakemore strawberries grown under a previously fruited thinned row system, significantly greater yields were obtained from the renewal system by which all runners were removed and the original plants fruited the second year than from either the conventional renewal system or reversion to the matted row. It is indicated that when thinned rows are allowed to revert to a matted row condition for second-year fruiting, yields equal to a conventional "barring off" may be obtained. Compared with the first-year yields, fruiting the original plants the second year resulted in only a small reduction in yield of approximately 8 per cent, whereas with the other two renewal systems, decreases of approximately 40 per cent occurred. This is primarily due to the fact that plants under the 2-year plant renewal system were able to accumulate larger leaf areas, root systems, and food reserves as reflected by the dry weight data presented.

Greater yields per acre were obtained from the 10-inch width rows with progressively lower yields from the 20-, 30-, and 40-inch width rows. This is consistent, regardless of the renewal system employed, with the results obtained during the first season of fruiting (1).

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1. CRANE, J. C., and HAUT, I. C. Relationship of width of thinned row to productiveness and quality in the Blakemore strawberry. *Proc. Amer. Soc. Hort. Sci.* 38: 417–419. 1941.

Growth and Fruiting of the Cranberry[1]

By R. H. ROBERTS and B. ESTHER STRUCKMEYER, *University of Wisconsin, Madison, Wis.*

THE cranberry shows a consistent relationship betwen the length of growth made by the uprights and the amount of fruit produced (Figs. 1, 2). From Fig. 2 and Table I and numerous similar data, it is apparent that large yields are secured when the average growth is between 2½ and 3½ inches long. This is found to be the optimum growth for several varieties, although the largest yields are found on McFarlin's with somewhat shorter growths than is the case for Howes.

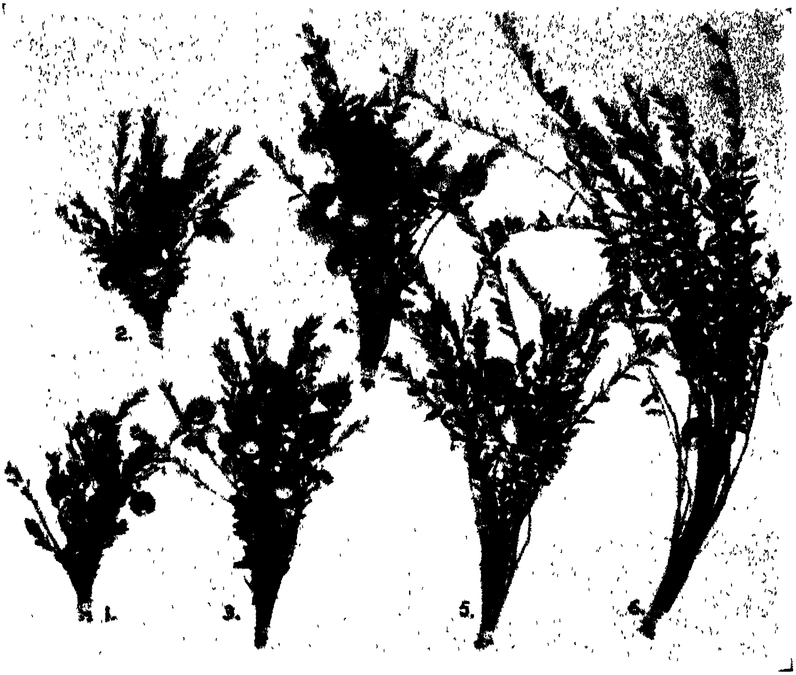

FIG. 1. Growth and fruiting of Searls; 25 uprights per bunch. 1, 10 to 40 fruits, 60 to 80 uprights per square foot; 2, 60 to 80 fruits, 140 to 160 uprights per square foot; 3, 90 to 120 fruits, 200 to 240 uprights per square foot; 4, 140 to 160 fruits, 260 to 280 uprights per square foot; 5, 60 to 80 fruits, 320 to 360 uprights per square foot; and 6, 5 to 20 fruits, 400 to 500 uprights per square foot.

The difference in optimum growth for these two varieties is not more than ¼ inch.

One of the principal factors affecting growth and production is the population or stand of uprights (Fig. 2). Optimum growth and maximum production are found when the number of uprights is from 200

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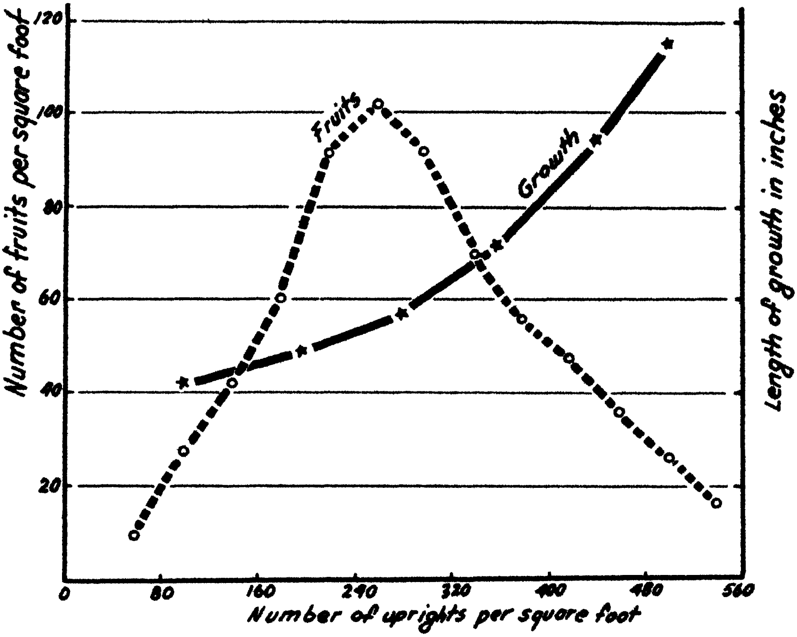

FIG. 2. Graph showing the relation of stand of uprights to fruit production and to length of uprights.

to 300 per square foot. As the number of uprights increases the length of the growth also increases, apparently as the result of shading. As an

TABLE I—PRELIMINARY NOTES ON THE RELATION OF GROWTH AND FRUITING OF CRANBERRIES, 1939

Notes on Growth or Fruiting	Age	Estimated Yields (Barrels)*	Uprights Blossoming 1939 (Per Cent)	Fruits per 100 Uprights	Length 1938 Veg.†	Length 1938 Blos.	Length 1939 Veg.	Length 1939 Blos.	New Buds‡ (Per Cent)	Repeated Blossoming (Per Cent)
Searls Variety										
Over-vegetative . .	22	10–15	27.0	4	4.8	3.5	4.7	4.3	36.9	58.1
Under-vegetative	22	20–30	24.2	18	1.9	2.9	2.1	2.3	39.6	55.5
Medium growth . .	22	125–150	36.0	44	3.3	3.1	3.1	3.6	46.1	34.8
High yields	22	125–150	44.0	58	2.8	3.2	3.2	3.7	41.3	19.5
"On-year"**	25	100 +	46.0	52	2.2	2.8	2.4	2.7	30.7	12.5
Howe's Variety										
Over-vegetative . .	14	10–15	34.0	3	—	—	6.2	6.1	51.9	64.7
McFarlin Variety										
Poor growth	14	40–50	48.0	24	1.9	2.4	1.9	2.6	50.0	44.7

*The number of berries per square foot indicates the approximate number of barrels per acre.
**A marsh which reportedly bears in alternate years.
†Vegetative or non-blossoming uprights.
‡Percentage of uprights forming blossom buds.

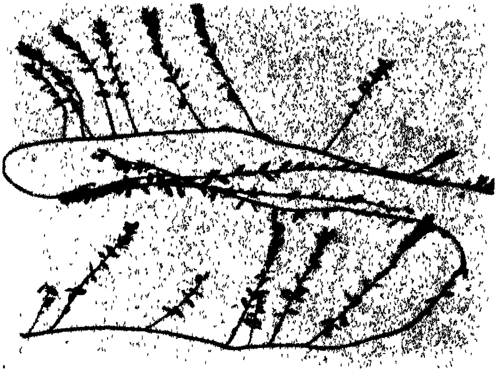

FIG. 3. Uprights arise from runners. When the plants are vigorous enough to produce runners, the population of uprights increases rapidly.

illustration, the relatively small effect of the shade produced by single cheesecloth coverings on four pairs of "pollination cages" set up as blossoming approached, which is near the close of the growing period, increased the length of growth by 48.2 per cent. Thinning the stands by pruning reduces the amount of growth, apparently as a result of increased light. In this same connection, it is interesting that mowing of very vegetative stands of vines gives a reduced length of growth until such time as high populations of uprights are again established. Excessive numbers of uprights result when the vines are vigorous enough to produce many runners (Fig. 3).

If any attempt is made to alter or control the amount of growth, it is important to remember that a proper growth of about 3 inches is made by about the time the blossoms open (Fig. 4).[2]

It seems that the failure of blossom buds to be formed in sufficient numbers to give a reasonably good crop is rare. The production of good crops depends more upon the set of blossoms than upon the formation of blossom buds. Table I shows that repeated blossoming if not fruiting is very common (also Fig. 5).

TABLE II—SET OF FRUIT IN "POLLINATION" CAGES AND UNDER BURLAP SHADES PUT ON AT START OF BLOSSOMING PERIOD

Variety	Fruits Per 100 Blossoming Uprights					
	Open Pollinated	Cage	Cage and "Brushing"	Shade to Jul 15	Shade to Aug 6	Pruned
			Year 1940, Biron Marsh			
Searls	72	16	56*	38	4**	111†
McFarlin	82	11	74	—	—	—
Howes	68	—	—	10	0.3	156
			Year 1941, Biron Marsh			
Howes	81	13	63	—	—	—
Searls	92	10	70	—	—	—
			Year 1941, Cranmoor Marsh			
Howes	100	11	58	—	—	—
Natives	138	18	74	—	—	—

*The sets of fruit in the cages is lowered by the shading effect of the cheesecloth covering.

**The effect of continued shading after the blossom period indicates a nutritional influence upon fruit set.

†The increased set following pruning is obviously the result of better light relations in plantings which were too thick.

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[2] Data collected by Mr. Ermon Bennett and Mr. Newell Jasperson, Cranmoor.

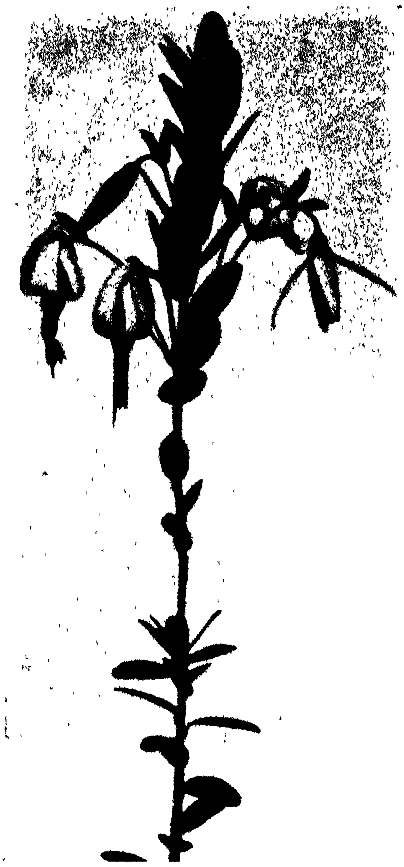

FIG. 4. Optimum growth of about 3 inches is completed by the time the plants come to blossom.

The poor crops of fruit on the more vegetative uprights in areas of high populations (Fig. 2) appear to be due both to shading and to poor pollination. The quality and character of the blossoms and new growth is much affected by artificial or natural shade as by weeds or thick stands of uprights (Fig. 6). The relation of this condition to the failure of blossoms to set is difficult to appraise. Its effect upon pollination can be more readily evaluated.

Blossoms on plants inclosed in cheesecloth cages during the blossoming period set few fruits. This may be argued as the result of excluding insects. It is very interesting that good sets of fruit are secured on plants under similar cages if the uprights are brushed by such means as a stick, or a paddle (Table II). Apparently pollination can be affected in the cranberry merely by agitation of the blossoms as by a breeze. This becomes clearly understandable after noting the structure of the blossom.

Fig. 7 shows in diagram some details of the cranberry blossom. The blossoms bend down (forming "hooks") shortly after beginning to grow in the spring. This habit makes pollination possible. The anthers (a) do not dehisce pollen directly into the air as is common with most species of

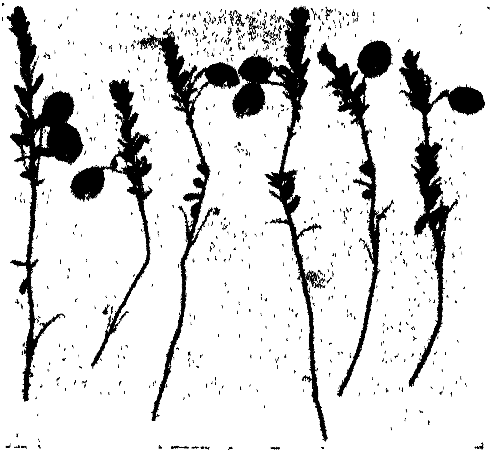

FIG. 5. Repeated blossoming is common on moderately vegetative uprights.

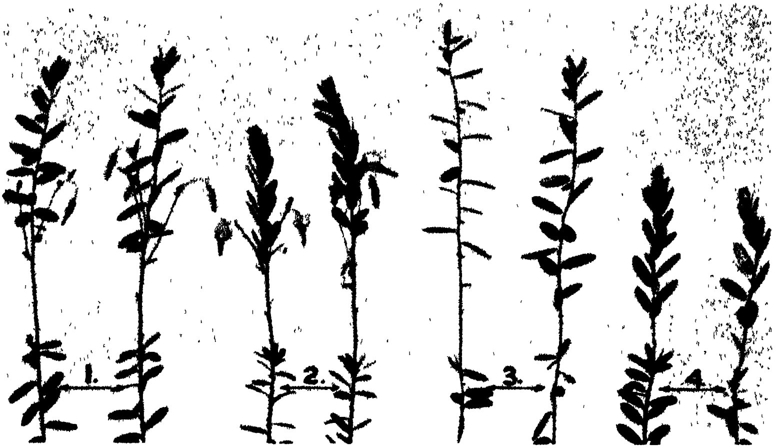

FIG. 6. Shade changes the type as well as amount of growth, Searls. Note effect on leaf angles and "spindlyness". 1, 3, Growing in shade; 2, 4, growing in sunlight.

plants. In the cranberry, the ripe pollen is delivered into long hollow "tubes" attached to the anthers (t). As the blossom begins to open (Fig. 7, E) the pollen is liberated in close proximity to the stigma of the pistil which by then has grown to be equal in length to the anther tubes. Jarring at this stage of flower development liberates quantities of pollen into the air about the pistil. Emasculation and hand pollination operations have shown that the stigma is receptive at this stage of blossom development.

Pollination is apparently brought about by wind-borne pollen reaching the pistil. This is not effective through any great distance as emasculated blossoms left in the open rarely set fruits.

When honey bees visit the blossoms in search of nectar, they do not usually touch the stigma. The jarring of the blossoms during their visits would appear to be of prime importance in any aid to pollination which they render.

Cranberry blossoms open rapidly. They may reach "full blossom" (Fig. 7, F) in as short a time as 2 hours under favorable weather conditions.[3] It appears that wind or other jarring of the opening blossoms is desirable for effective pollination.

Another peculiarity of the cranberry blossoms which aids fruit setting is that the pollen is not a simple grain as is usually the case in plants but is a tetrad. It is apparently capable of germinating into four functional pollen tubes (Fig. 8).

Another fortunate circumstance is that fruits may set with very few seeds maturing. In fact, seedless fruits are not uncommon. The number of seeds in berries of Howes, McFarlin, Natives and Searls under different conditions are shown in Table III.

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[3] Added observations of this detail were furnished by Mr. Ermon Bennett and Mr. Newell Jasperson, Cranmoor, Mr. C. L. Lewis, Jr., Beaverbrook, and Dr. Phileo Nash, Biron.

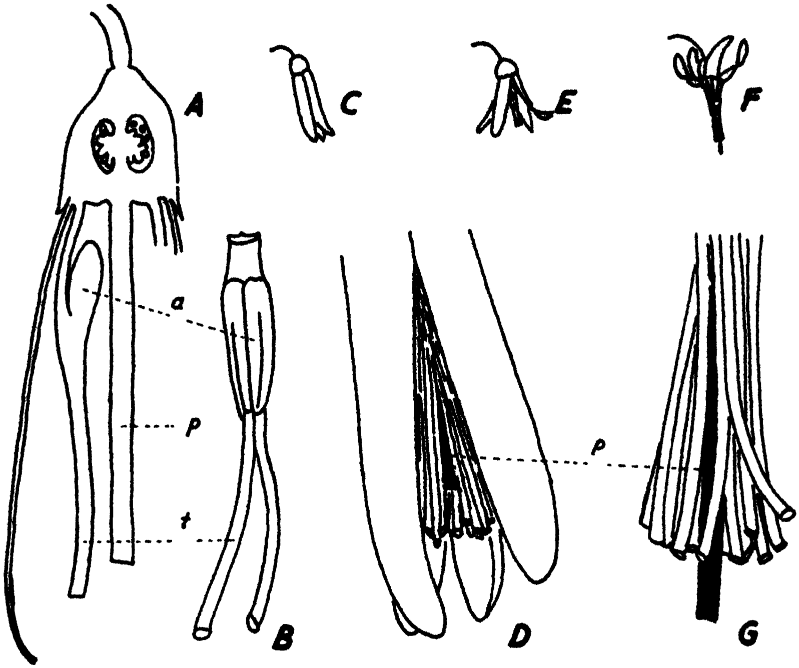

FIG. 7. Diagrams of the cranberry blossom and its development. A, Blossom in section just before opening showing anther (a), anther "tube" (t), and pistil (p). B, Anther in face view, showing hollow anther tubes (t). C, Blossom beginning to open. D, At stage C the pistil (p) is just shorter than the anther tubes. E, One or two hours after C; pollen is now dehiscing. The pistil is equal in length to the anther tubes and the stigma is receptive. F, Two to several hours after stage E. G, At stage F the pistil is longer than the anther tubes.

Cranberry pollen does not shed readily when the blossoms are in damp situations. This brings the discussion back to the matter of populations of uprights. The poor sets of fruit where the vines are too thick could be the result of excessive dampness, shade, and lack of adequate jarring of the blossoms by either insects or wind.

Whatever the numerous factors may be which are credited with causing good or poor crops of cranberries, an outstanding fact is the consistently observed relation between production and amount of growth, particularly as it is affected by populations of uprights.

TABLE III—SEED NUMBERS, 1941

Location of Blossoms During Blossom Period	Number of Seeds			
	Large Fruits	Medium Fruits	Small Fruits	Average
In sunlight	13.1	10.5	7.2	10.2
Shade of thick uprights	11.1	9.3	4.7	8.4
In cages	6.5	3.1	1.4	3.6
"Brushed" plants in cages	8.0	4.8	3.3	5.4
Outside near cages	11.1	8.6	5.8	8.5

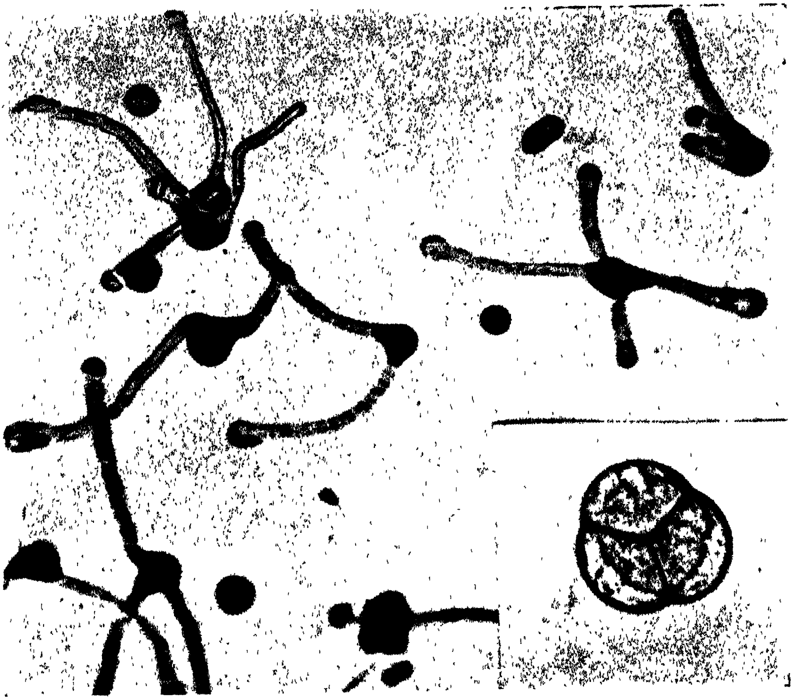

FIG. 8. Cranberry pollen "grains" consist of four cells, each capable of producing pollen tubes. Insert, more enlarged grain.

The next problem is: Do these same relations of growth and fruiting prevail without regard to the combination of environmental factors which are used to produce optimum growth?

The degree to which optimum growth conditions for fruiting may shift with variety, location or culture is yet to be determined, but it is now obvious that the amount and type of growth being made is closely corrrelated with cropping. It is also very evident that no fixed cultural treatment will give the desired yields as some areas of a marsh may need to be made more vegetative and others less vegetative to be more productive. A very prevalent situation in Wisconsin marshes is too much growth and the consequent cultural problem is, that of devising a practical means for reducing the amount of annual growth.

A Method of Photographing Plants in the Field

By R. E. Wester and Roy Magruder, *U. S. Horticultural Station, Beltsville, Md.*

TO PREVENT movement of foliage by air currents and to eliminate the deep shadows occurring in strong light in photographs of plants made in the field, the authors have devised an inexpensive portable field photographic "studio" that is described herein.

As shown in Figs. 1 and 2, the subject is surrounded with hotbed sash and a covering of cheesecloth or canvas is used to prevent air movement and to allow entrance of sufficient light. By use of different combinations, areas of various sizes can be enclosed.

In Fig. 1 the ground area is approximately 7 by 9 feet. The three sash on each side are supported by posts and light-weight cross members nailed along the top of the posts. The background shown is 4 by 7 feet and is made of fiber board painted with a flat white or very light yellow paint. The fiber board is given rigidity by a light-weight wooden frame. The cross lines which are spaced 1 foot apart are made of heavy black linen thread stretched tightly and held in place by thumb tacks along the edge of the frame.

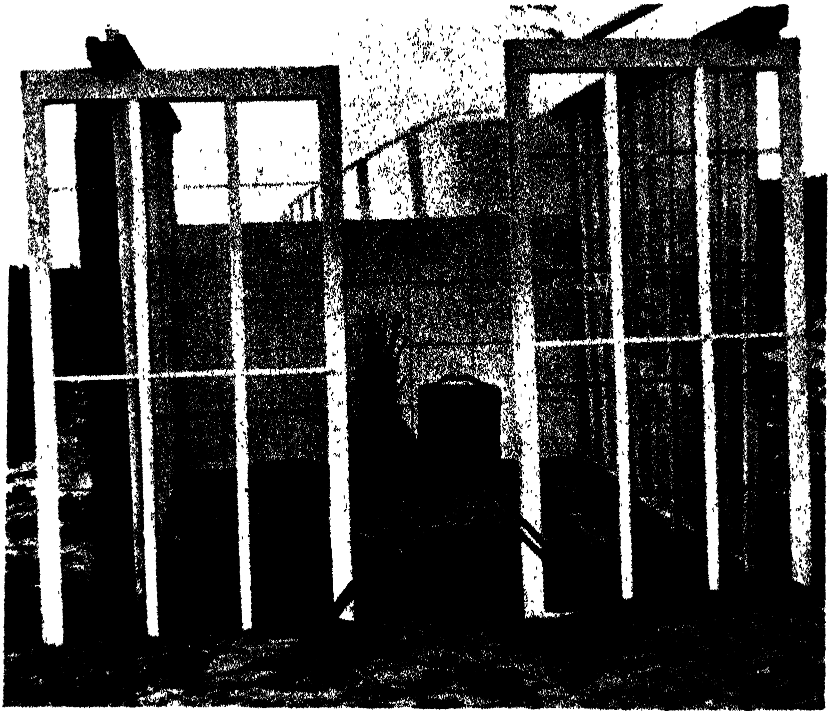

FIG. 1. Portable field photographic studio. Note the indistinctly shown cheesecloth above the fiber-board background and across the top, which serves to diffuse the light and prevent air movement. Another background section may be placed on top of this one making a field 7 by 8 feet in size.

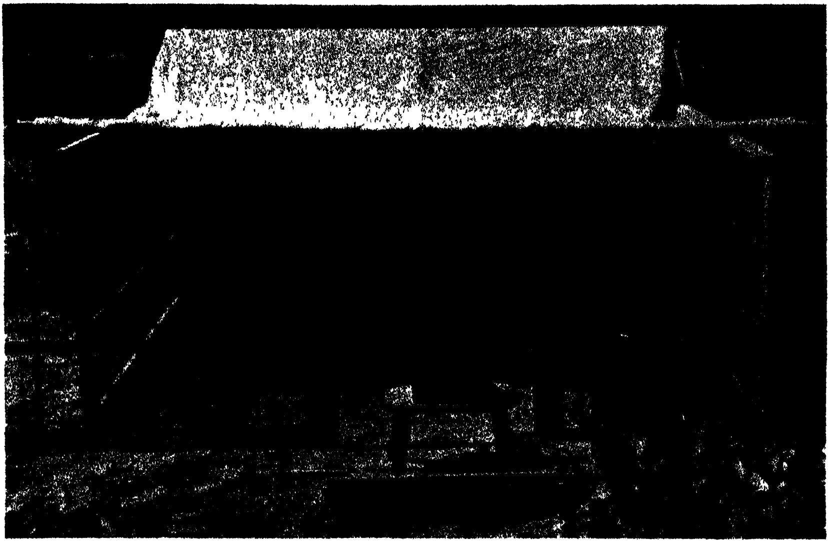

FIG. 2. Modification of portable field photographic studio. A set-up for short plants showing the canvas used on bright days to prevent deep shadows in the plant and on the background. The front sash are not necessary except on very windy days.

For tall plants, the background may be placed on end, and for plants larger than 4 by 7, two or more such background sections may be screwed or bolted together. When they are placed end to end, variation in character of row planted crops may be shown.

Use of cheesecloth, muslin or canvas precludes the necessity of waiting for a dull or cloudy day in order to avoid the strong contrasts produced by bright or intense light. In Fig. 1 cheesecloth has been used as a covering to diffuse the light and to prevent wind movement of the foliage. In Fig. 2 the top cover is a clean piece of canvas rolled on a pole to facilitate handling. When the shadows cast by the sash bars (seen on the left side of Fig. 2) enter the photographic field they are eliminated by covering that side with a piece of canvas or cardboard. A sheet of white or light colored cardboard is useful foi reflecting light into the darkened side when the sun is relatively low on one side or the other. Although this arrangement may be set up in any direction, less difficulty in lighting is encountered if the camera points to the north.

In taking a large number of photographs of plants of approximately the same size but of different varieties we use the following procedure: The camera is set up to take in sufficient field for the largest plant and is adjusted by use of tripod, stool or other suitable support to mid-height of the plant, thus preventing distortion. The lens is stopped down to give clear definition with greatest desired depth of field. A selected plant is then dug up with as much soil adhering to its roots as can be easily handled and it is placed in the hole from which the plant used for focusing was removed; the soil is smoothed out; leaves and fruit are arranged; photometer reading is obtained; the front sash is placed if necessary; and the proper exposure is made. Two persons working together can accomplish this sequence in about 3 minutes or before plants such as peppers and eggplants start to wilt, if the plants do not have to be moved farther than 100 feet. A considerable number of photographs can, therefore, be obtained in one day if the plants can be sacrificed and the selection, pruning, and other preparation can be done in advance.

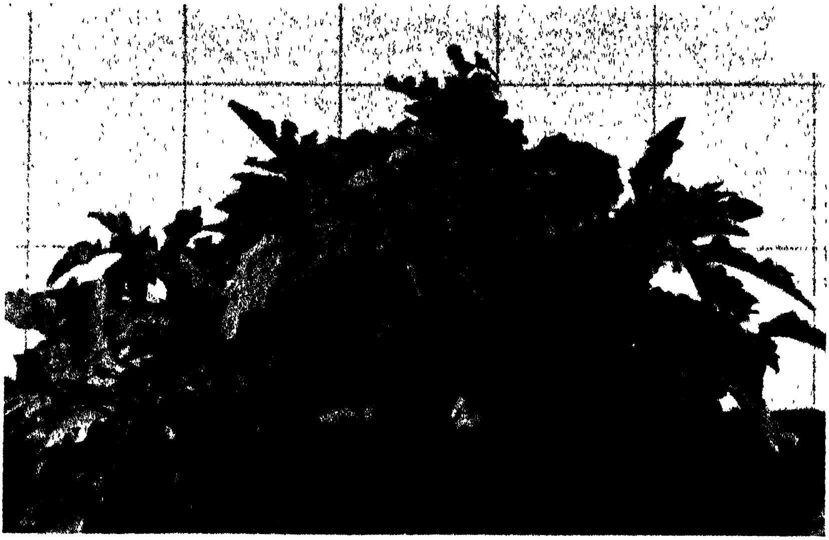

FIG. 3. A plant and fruit of New York Improved Purple eggplant taken in the arrangement shown in Fig. 1. Note the absence of deep shadows on the background and plant and the depth of field and detail made possible by small aperature and long exposure. The lines on the background are 1 foot apart.

Fig. 3 is an illustration of the kind of photograph obtained with the arrangement shown in Fig. 1. It has good detail and depth of field and shows size as well as other varietal characteristics.

If photographs are to be taken from the same material at intervals throughout the growing season, the sides shown in Fig. 1 may be left in place. The top and background should be stored under cover to prevent damage by rain.

Tetraploidy in Tomatoes Induced by the Use of Colchicine

By Edw. C. Stair and Robert K. Showalter, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

MANY methods have been used for making colchicine treatments on plants. It is a water soluble substance, is quite stable and not affected by light or standing for a period of time before being used. In general, it has been reported that the drug should be brought in contact with the growing tissues where mitosis is occurring most rapidly. However, it has been found to be effective by various injection methods, immersion of plant parts, spraying and dusting, and by means of seed treatments. In seed treatments the largest percentages of tetraploids have been induced where only small amounts of liquid have been used. By this method sufficient oxygen can get around the seed to enable it to germinate.

Blakeslee and Avery (1) worked with a wide range of concentrations varying from 0.003125 per cent to 1.6 per cent for 10 days in treating Datura seed. They found that with a 0.2 per cent solution they were able to produce 50 per cent tetraploids but all concentrations lower than 0.2 per cent were ineffective. With various concentrations up to 1.6 per cent they were able to produce slightly higher percentages of tetraploids.

Smith (5) treated tobacco seed for 7-, 10-, and 14-day periods with 0.2, 0.4, and 0.8 per cent colchicine solutions. He found that polyploid seedlings could easily be produced by this method, but there was some difficulty affecting the meristem enough to produce polyploidy in the inflorescence without inhibiting growth in the stem and roots.

The seedlings of plants are sometimes treated by immersing the growing tips into the solution. Dermen and Darrow (3) used this method successfully to induce tetraploidy in strawberries. Nebel and Ruttle (4) used these immersion methods with 0.2 and 0.4 per cent solutions for 1- to 24-hour periods. They treated marigolds, petunias, snapdragons, pinks and tomatoes. Three varieties of tomatoes were treated with colchicine in both aqueous solution and lanolin. Tetraploids were produced by both types of treatment. Chromosome counts made from root tips showed 48 chromosomes. The tetraploid plants produced were non-fruitful.

In the experiment here reported three methods of treatment were used. The first method consisted of immersing the tips of young vigorously growing tomato plants in vials of colchicine solution for various periods of time. The plants were about 5 inches tall and were growing in 4-inch clay pots. The Indiana Baltimore variety was used for all treatments. The aqueous solutions contained 0.025, 0.05, 0.1, 0.2, 0.4 and 0.8 per cent colchicine and the treatments were for 3, 6, 12, 24, and 48 hours. The colchicine solution was placed in glass vials which were imbedded in the soil of the pots near the base of the plants. The plant was bent over and the growing tip placed in the vial so that it was immersed in the liquid. There were 10 plants in each treatment. The 0.8 per cent solution for 24 hours produced two tetraploid plants. None of the treatments of lower concentration or for shorter lengths of time were effective. At 48 hours a 0.2 per cent solution produced one tetraploid plant and with an 0.8 per cent solution four out of five plants were tetraploid.

The second treatment consisted of soaking the seeds in various concentrations of colchicine in aqueous solution for different periods of time. The seeds were placed in Petri dishes containing 0.00, 0.0125, 0.05, 0.1, 0.2, 0.4, 0.8 and 1.6 per cent colchicine and the solution was quite shallow in order to provide sufficient oxygen for good germination.

In this series, 1 day in 1.6 per cent solution produced 2 tetraploid plants out of 10; 2 days at 0.8 per cent produced 2 tetraploid plants out of 10; and 2 days in 1.6 per cent produced 2 large tetraploid plants. Seed soaked 4 days in 1.6 per cent solution produced only two plants which lived and one of these was tetraploid. Soaking 8 days in a 0.4 per cent solution gave nine plants, two of which were small and dwarfed and soon died; and seven normal plants. After 8 days in 0.8 per cent solution, 5 out of 10 plants were tetraploid. The 16-day treatment was not effective because it injured the viability of the seeds.

The third set of treatments consisted of dropping a 0.4 per cent solution of colchicine on the growing tip of the plant. The plants received 1, 2, 4, 8, 16 and 32 drops at 2-hour intervals for a 13-day period. None of these treatments proved effective.

Plants from all treatments were set in the field and observations

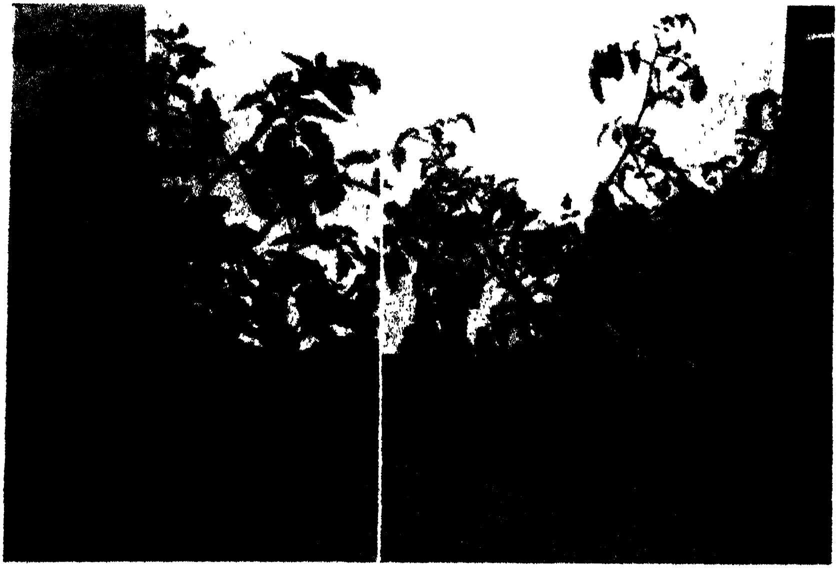

FIG. 1. Showing a tetraploid tomato plant on the left and a diploid plant on the right.

made at frequent intervals during the summer. Large flowers, heavy stems, and dark green, crinkly leaves distinguished the tetraploid from the diploid plants (see Fig. 1). Pollen grains from the tetraploids were twice the size of normal pollen grains. These plants were also conspicuous because they bore only very few fruits or were barren. The fruits that were produced were small and solid and had few or no seeds.

Seed samples were saved from all treatments and from each individual tetraploid plant that produced fruits with seeds. Plants were grown from these seeds and set in the field in 1941 to see what effects would show up the second year. Seed saved from plants which showed no effect the first year produced normal diploid plants the second year. All of the seeds from tetraploid plants produced large non-fruitful tetraploid plants the second year.

The tetraploid plants produced by the colchicine treatments can easily be distinguished from the diploids, even in the seedling stage, but the surest method is to count the chromosomes. When the root tips were imbedded in paraffin, sectioned and slides prepared, it was found that 48 chromosomes were present. The camera lucida drawing in Fig. 2 shows the arrangement of the chromosomes as seen in the telophase stage.

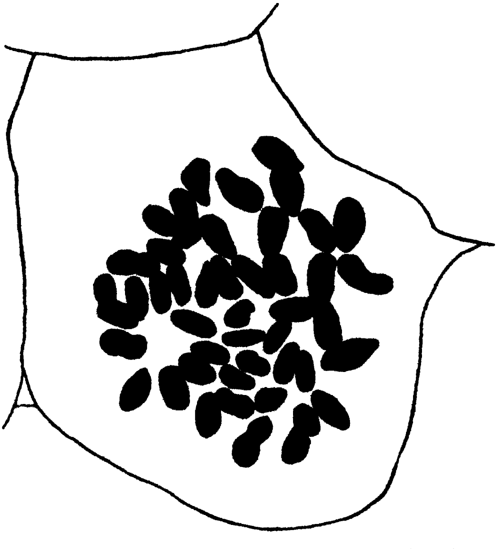

FIG. 2. A camera lucida drawing showing 48 chromosomes in the cells of the tetraploid tomato plant.

CONCLUSIONS

This experiment has shown that tetraploid tomato plants can be produced by the use of colchicine. Tetraploidy in tomatoes is transmitted to succeeding generations. The production of tetraploids in common market size tomatoes would appear to be of no commercial value insofar as increased size of fruits or yields is concerned. It is, however, assumed that this technique might be of value in a tomato breeding program for the purpose of crossing some rather distantly related species.

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Genetics of Cultivated Cucurbits

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Abstract

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RECENT papers dealing with the genetics of cucurbits have increased the total number of known allelic pairs for watermelon from six in 1937 to 25 for qualitative characters, which result from the interaction of 14 pairs of genes and one triple allelic series. Three linkage groups are now partially identified. Twelve to 13 pairs of genes for weight inheritance have been estimated to be segregating in a cross and backcross between a 7-pound and a 17.5-pound fruit. Estimation of gene number in quantitative inheritance depends on calculation of a genetic standard deviation from field data, which is then compared with the binomial standard deviation of $[1 + (n+1)]^n$ which corresponds in its geometric mean to the observed population geometric mean.

Papers dealing with cucumber genetics have brought the total number of identified character pairs to about 17 for qualitative characters, some of which are caused by genes with pleiotropic effect often doubtfully interpreted as complete linkage. One measurable linkage is now reported.

New information on muskmelon genetics deals entirely with inheritance of new sex forms, of which two, gynomonoecious and hermaphrodite, have been genetically analyzed in addition to monoecious and andromonoecious previously known. From an uncompleted study one investigator believes a total number of 15 genetically determined forms will be obtained.

B-Napthoxyacetic Acid as an Inductor of Parthenocarpy in Tomatoes[1]

By Felix G. Gustafson, *University of Michigan, Ann Arbor, Mich.*

ZIMMERMAN and Hitchcock (4) and Zimmerman (3) have recently discussed the influence of B-naphthoxyacetic acid (NOA) upon plants. They found that among other activities it induces parthenocarpy in tomatoes. During the past summer, the writer has employed this chemical to induce parthenocarpy in the tomato varieties John Baer, Valiant, Master Marglobe, Rutgers, and Stokesdale, grown in the field. As usual, the chemical was mixed with lanolin and applied to the cut style (1). Concentrations of 0.25, 0.5, and 1.0 per cent were used.

From Table I it will be seen that the parthenocarpic fruits were in all instances larger than the corresponding seeded fruits. The results were especially striking with the Master Marglobe and Rutgers, in which the average increase was 39 per cent (with 0.5 per cent) and 27 per cent (with 0.25 per cent) respectively, and the others showed an increase of 8 per cent or more. The fruits measured were located in the 1–4 positions in a cluster, and most of them were in the 1–2 positions. In order to insure that there was no undue advantage given to either the seeded or seedless fruits, they were alternated in the clusters as far as possible, and when that was not possible, seeded fruits of the same degree of ripeness were picked from the same position as the seedless fruits from different clusters. The 1 per cent paste was found to be too concentrated and some injury was observed, but neither of the other concentrations produced any blemishes on the fruits. In John Baer the parthenocarpic fruits were a little longer and more

TABLE I—A Comparison of the Size of Parthenocarpic Fruits Produced by B-Naphthoxyacetic Acid and Seeded Fruits (Size is Given as the Diameter in Centimeters)*

Name of Variety	Treatment				Number of Fruits Measured	
	0.25 Per Cent NOA	0.5 Per Cent NOA	1.0 Per Cent NOA	Pollinated	Parthenocarpic	Seeded
John Baer	7.622 (54)*	8.231 (57)	7.847 (48)	7.179 (141)	159	141
Valiant	7.640 (44)	—	—	7.494 (36)	44	36
Master Marglobe	7.838 (21)	9.30 (20)	—	6.706 (33)	41	33
Rutgers	8.75 (30)	7.161 (18)	—	6.773 (41)	48	41
Stokesdale	7.422 (40)	—	—	6.842 (45)	40	45

*The figures in parentheses denote the number of fruits measured.

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[1] This research has been aided financially by the Horace H. Rackham Trust Fund of the University of Michigan. The chemical was supplied to the writer by Dr. John C. Sheehan of the Chemistry Department and by Dr. P. W. Zimmerman of the Boyce Thompson Institute, and to them he expresses his appreciation.

slender than usual; no difference in shape was noticed in the other varieties. Internally, the fruits were all normal except for the lack of seeds.

From the practical point of view, it is very important to know something about the amount of setting; the fruits may be larger with the chemical treatment, but if setting is poor, the chemical treatment would be valueless. Therefore the percentage of setting, both with the chemical treatment and pollination, has been determined and this is presented in Table II. Only in John Baer were the flowers hand-pollinated; in the other, buds similar to the treated ones were tagged and left for open pollination. It should be emphasized that early in the season a larger percentage of blossoms produced fruits than later in the season. For this reason the setting of fruits in flowers treated early in the season with 0.25 per cent NOA is shown separate, as well as included in the whole season's setting. When only those blossoms treated early are considered, the setting is very high, but when the flowers treated late in July are also included the percentage falls considerably, but this is also true for those blossoms left for open pollination in Valiant, Marglobe and Rutgers. Comparing the setting for the whole season, the chemical is much more effective in Valiant and Rutgers than is pollination, whereas there is no great difference in the Marglobe. No comparisons can be made in John Baer and Stokesdale because pollination was noted only early in the season. One per cent was used with John Baer only, on July 4, and that probably accounts, at least partly, for the high percentage of fruits produced. From the data presented in Table II, it is safe to assume that the setting with chemicals is at least as high as with open pollination and considerably higher in some varieties.

TABLE II—PERCENTAGE SETTING WITH B-NAPHTHOXYACETIC ACID AND POLLINATION

Treatment	John Baer†	Valiant	Master Marglobe	Rutgers	Stokesdale
Pollination	80.0 (16)* (early in season)	50.0 (20)	66.0 (15)	25.0 (15)	90.0 (10) (early in season)
1.0 per cent NOA	96.0 (50)	—	—	—	—
0.5 per cent NOA	71.0 (80)	—	73.0 (28)	60.0 (30)	—
0.25 per cent NOA early in season	94.3 (35)	—	94.0 (10)	89.0 (28)	—
For whole season	72.0 (75)	73.3 (60)	70.0 (30)	79.0 (38)	80.0 (50)

*The figures within the parentheses denote number of buds treated.

†Only in John Baer were the flowers hand-pollinated; in all others, buds of the same stage of development as those treated with chemical were tagged and left for open pollination.

One can, with a high degree of assurance, state that B-naphthoxyacetic acid should prove a very useful chemical in the production of seedless fruits in tomatoes, or for that matter to increase the total setting, whether seeded or seedless.

Besides the lanolin paste method several other methods of producing seedless fruits were also tried. Fifteen clusters with buds just ready to open, or opened, were sprayed with an aqueous solution of 100 milligrams of NOA per liter. A few seedless, more with few seeds and some normally seeded fruits were the results. This method seems to be fairly efficient if the flowers are just in the right stage of development when sprayed, but not otherwise. Spraying would have to be done every few days.

In order to continuously supply the cluster with the chemical to act upon the flower buds as they become ready, a ring of lanolin paste containing 1 per cent NOA was placed just below a cluster with the first buds nearly ready to open. Only seeded fruits were produced. Theoretically, this method should work, because the chemical continues to diffuse out of the lanolin for a long time, but as there was no prevention of pollination, seeds were also produced. It would seem that in the greenhouse where pollination is not so likely, this method may bring about a high percentage of setting, either with or without pollination.

SUMMARY

Seedless fruits produced with B-naphthoxyacetic acid were larger than seeded fruits produced by pollination. Setting was also somewhat greater than with open pollination.

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Breeding Summer Tomatoes for Increased Size[1]

By Leslie R. Hawthorn, *Texas Agricultural Experiment Station, Winter Haven, Tex.*

IN 1937, Yarnell and Hawthorn reported the progress which they had made in Texas in lengthening the tomato fruiting season through a program of plant breeding (3). This extension of the fruiting season as explained in that report was essentially the development of varieties which would produce fruit in the Southwest during the period between the spring and fall crops. This period is characterized by high temperatures and low relative humidity. As indicated in the above report, the Station distributed at about that time under the name Summerset, a new variety which through a process of selection had come from the cross, Large Cherry x Bonny Best, made in 1933 at the Winter Garden Substation. Since that time Summerset has been widely tested in Texas, Oklahoma, and elsewhere, and has become established as a useful home garden variety in certain areas of those states. In 1940 it was taken over by a Texas seedsman and was distributed in 1941 through regular trade channels.

With such varieties as Red Cherry and related small fruited kinds, the new Summerset, and other varieties adapted to summer conditions the problem of producing summer fruit is in one respect solved. However, since even the largest fruited of these varieties is still small by commercial standards, a large fruited summer tomato is still needed. Hence work along this line has been and is being continued.

Definite progress towards larger size was, of course, made in the development of Summerset, when it is remembered that the original starting point was the small Red Cherry. In the report describing that work a record is given showing that Large Red Cherry averaged over twice the weight of Red Cherry at the crucial period towards the end of August in 1936 (3). At the same time the selected lines from which Summerset later came were producing fruits nearly three to over three times the weight of Large Red Cherry. Whereas Red Cherry had 16 fruits per plant, Large Red Cherry had 8.5, and the pre-Summerset selections had from 2.4 to 4.7 fruits per plant. Summerset today has fruits 1½ to 2 inches in diameter, and 1⅜ to 1½ inches in depth.

In the fall of 1938 reciprocal crosses were made between Summerset and Bison. The latter variety was introduced in 1929 by the North Dakota Agricultural Experiment Station and came from a cross between Red River and Burpee's Self Pruning followed by several years of selection (5). Among a collection of varieties grown at Winter Haven during the summer of 1938, Bison had not only set fruit as well as Summerset, but its fruits were sometimes larger as well (Table I). Drawbacks to the variety were the frequent roughness and irregularity of the fruits, as well as their uneven development of color, and the very determinate habit of the plants. This last characteristic made them extremely small and left the fruit unprotected and subject to sunscald. These unfortunate characteristics detracted from the usefulness of the

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[1] Approved by the Director as Technical Contribution No. 709 from the Texas Agricultural Experiment Station.

TABLE I—FRUIT WEIGHT AND YIELDS PER PLANT OF THE PARENTS AND RED CHERRY GROWN IN 1938

Variety	Average Weight of Fruit (Gms)		No. Ripe Fruit Per Plant Sep 6
	Aug 24	Sep 6	
Red Cherry	—	2.3	26.2
Summerset	24.5	20.0	1.2
Bison	18.1	28.1	3.6

variety for the Southwest. Crossing Bison with Summerset, however, brought together *two* parents which would set fruit in the summer. Both had different backgrounds of development, and Bison, unlike Summerset, had a pedigree which lacked the tiny Red Cherry (1).

No detailed fruit data were collected on the F_1 population in 1939. General observations indicated that the plants, which were all indeterminate in habit — like Summerset, produced prolifically through the summer. The fruits were possibly slightly larger than Summerset, but not strikingly so. In general they were smooth and well shaped.

In 1940 a collection of 1,600 F_2 plants was set in the field. This included 617 plants of a Bison x Summerset cross, 515 plants of a Bison x pre-Summerset selection, and 468 plants the reciprocal of the latter. The latter was a line out of the original Large Cherry x Bonny Best cross. It had slightly larger fruit than Summerset, but did not set as well in the crucial summer period, and so was not included in the several practically identical selections which were thrown together and named Summerset. Seed for this planting was sown April 12, the plants were moved to the field May 27, thus allowing them to come into bearing in early August, an excellent time to observe their behavior

During the first two weeks of August, 39 plants of indeterminate habit were selected. Each plant was selected on a basis of large fruit and obvious productivity. Although large fruit was the more important requirement, high productivity had to accompany it; a plant without both was not taken. The shape and general appearance of the fruit was a third but minor consideration in selection. Only a few of the plants with fruits near the lower limit on size were discarded on account of roughness, and poor shape. In general, roughness and irregularity of fruit shape were common characteristics in the F_2 population. Individual harvest records were kept on each of the 39 plants from the time of selection up to and including September 11. Pickings were made every five days starting with August 5, so over half of the selections were picked eight times. This record gave a picture of a plant's regularity in bearing, its actual yielding capacity in terms of weight or number of fruit, and in addition the average weight of that fruit. While the numbers of fruit involved were perforce often small, and obviously there could be no replications, this numerical record was more helpful in picking out the more promising of the 39 plants than any series of narrative observations would have been. Table II gives an example of the type of data obtained from several of the better plants for three of the eight harvests. A comparison of the aver-

TABLE II—FRUIT WEIGHT AND YIELDS OF SELECTED F_2 PLANTS OF THE BISON x SUMMERSET CROSS FROM SAMPLE HARVESTS IN 1940

Single Plant Selection	Ave Weight of Fruit (Gms)			No. Ripe Fruit Per Plant		
	Aug 5	Aug 17	Aug 27	Aug 5	Aug 17	Aug 27
BS (bs) 2	166.5	136.1	45.4	3	5	2
BS(be) 2.	181.4	142.4	90.7	1	7	1
BS(be) 5	68.0	45.4	51.7	8	7	7
BS(be) 6*	122.9	90.7	——	7	9	0

*Although this plant had no ripe fruit on August 27, it produced two fruits averaging 90.7 grams on August 31.

age weights of fruit in this table with those in Table I indicates considerable improvement in size of fruit over the parent varieties, Summerset and Bison under unfavorable conditions, and of course much larger than Red Cherry from which the ability of Summerset to bear fruit under adverse conditions originally came. In considering the fruit size of these selections, it should be remembered that the fruit of most varieties tends to become smaller during the hot, dry summer period. Data were presented in 1937 showing that whereas the normal weight of fruit for Bonny Best is 125 to 155 grams, the average weight for the variety at College Station at the end of August in 1937 was only 24.7 grams (3). With the more moderate temperature and humidity of Fall, Bonny Best not only sets fruits more prolifically, but the fruits grow to the normal size. The summer varieties likewise increase in size with the coming of cooler weather and in addition begin to contain seeds. They do not however increase in size in the same proportion as Bonny Best. Nevertheless in 1940 a number of the F_2 plants had fruits in October and November of larger size than fruits of commercial varieties such as Stokesdale, Rutgers, Marglobe, being grown at that time. Summerset fruits, although somewhat larger than in the summer, still rated commercially as small.

As soon as seed became available in late October and in November (fruits are normally seedless until then), it was collected from the six most promising F_2 plants. Around 70 to 90 F_3 plants of each of these selections were set out in 1941 so as to come into bearing towards the end of July. Twenty plants were marked as promising early in August in the same way that the selections had been chosen in 1940. Individual harvest records through August and into September were again kept. Table III gives some data for three of the five harvests on some of the more promising plants.

Although yields of the individual progenies were not kept, the collection of 1941 as a whole produced more uniformly than did the one of 1940. There was still a wide variation of types ranging from the small determinate plant with small fruits to the large indeterminate plant with large ones. The progeny of plant BS(bs)2 contained the greatest number of promising plants, and thus the most selections were made from it.

This point is of interest because BS(bs)2 came from the cross Bison x Summerset and not from the cross Bison x pre-Summerset selection. It will be recalled that the pre-Summerset selection had larger fruit

TABLE III—FRUIT WEIGHT AND YIELDS OF SELECTED F_3 PLANTS OF THE BISON x SUMMERSET CROSS, AS WELL AS SUMMERSET AND STOKESDALE FROM SAMPLE HARVESTS IN 1941

Single Plant Selection	Ave Weight of Fruits (Gms)			No. Ripe Fruit Per Plant		
	Aug 21	Sep 12	Sep 29	Aug 21	Sep 12	Sep 29
BS(bs) 2–2	70.3	90.7	72.1	11	2	17
BS(bs) 2–4	105.7	90.7	105.7	3	2	3
BS(bs) 2–5	99.8	60.3	74.4	5	9	11
BS(bs) 2–8	99.8	60.3	84.4	5	3	7
BS(be) 2–4	85.3	45.4	37.2	8	3	11
BS(be) 2–7	77.6	22.7	56.7	7	1	4
BS(be) 6–1	96.2	34.0	30.4	8	4	3
Summerset*	24.0			26.8		Many
Stokesdale†	51.7			0.2		None‡

*Four plants.
†65 plants.
‡Not only none ripe, but none setting.

than Summerset, but did not set so well. All selections in the Summerset material with fruits larger than the normal for Summerset have always failed to bear well enough during the crucial summer period. This tendency showed itself in the F_2 population of the Bison — pre-Summerset crosses, where only 14 of the 39 plants originally selected came from the cross in question, and only one (BSd2), warranted inclusion in the final six selections from which seed was collected in 1940. Among the F_3 progeny coming from BSd2, not one plant warranted selection in 1941. In contrast, choice among the F_3 progenies of the Bison x Summerset cross was relatively difficult because of the large number of promising plants from which to choose. Practically all the plants in these progenies produced fruits of Summerset size or larger during the summer. The 20 plants selected were usually more prolific than most, and had larger fruits.

In Table III, one can compare the fruit size of some of the 1941 selections with that of Summerset. The smallest on August 21 was only slightly less than three times the size of Summerset, and the largest had fruits averaging over four times the weight of Summerset. All of these selections had fruits which averaged even larger than some fruit discovered on the variety Stokesdale. These only averaged 51.7 grams each. In the fall commercial season of 1940, Stokesdale fruits averaged as high as 124.7 grams each at Winter Haven. The number of fruit picked from each of the selected F_3 plants was also encouraging, and in striking contrast to Stokesdale (Table III). In the spring and fall seasons, Stokesdale as a regular commercial variety has borne fruit as prolifically as almost any variety tested at Winter Haven, and yet on August 21, only 14 fruits could be found on 65 plants of otherwise normal appearance. This was an average of 0.2 fruits per plant, in contrast to anywhere from 3 to 11 ripe fruits on the F_3 selections. These selections continued to bear all through the summer. On September 29, every plant of Stokesdale was examined, and no fruit of any kind could be found. This experience with Stokesdale is typical of others in past years with the well known commercial varieties.

A comparison of Table I with Table III reveals that Summerset produced an average of only 1.2 ripe fruits per plant on September 6, scale during three successive growing seasons. During the first three years the cross Grothen's Globe x Bison was used exclusively. The F_1 generation from this cross had previously been found to give a high early yield and seed was distributed to growers of early market tomatoes for trial. In 1941 the cross Michigan State Forcing x Cooper's Special was used for trial as a greenhouse crop. In addition, smaller quantities of seed of a number of different hybrids have been produced in the greenhouse from time to time.

METHODS OF HYBRIDIZATION

Early in the course of the investigations it became apparent that unstaked and unpruned tomatoes could not be used to advantage for the production of hybrid seed. Many physical difficulties were encountered because of the necessity of working on the ground. It is practically impossible to emasculate and pollinate all the flowers, thus necessitating the use of tags or some other means of identification. The time involved in placing identification markers on each cross-pollinated flower adds appreciably to the total labor involved; therefore, later experiments were confined to staked or trellised plants.

There appeared to be little choice between staking and trellising insofar as convenience or results were concerned. It was found very satisfactory to prune to two shoots. When individual stakes were used for each plant, a system of pruning which allowed more than two shoots to remain appeared to be impractical because of the bunching of the stems around the stake and the difficulty of getting at the flower clusters. The female parents used in these tests were indeterminate in habit of growth and well adapted to pruning and training in the usual manner. Some other system of handling the plants would have to be developed if a determinate variety were used as the female parent.

As the anthers of the tomato flower are fused together in a tube-like growth and also fused to the corolla at their base, it is relatively simple to remove the entire corolla and "anther tube" as illustrated in Fig. 1. Straight forceps with flattened tips were found to be the most satisfactory for this work. They are used to grasp the base of two petals, and a gentle pull will usually remove the combined corolla and anther tube. It is necessary to emasculate after the petals have separated and are slightly reflexed; otherwise they break off and the time consumed in removing the anthers is greatly increased. Emasculation must be carried out, however, before the petals are fully reflexed, as the anthers begin to dehisce before that stage is reached. The time of dehiscence in relation to the external appearance of the flower is influenced to some degree by environmental factors. It is undoubtedly a desirable practice to periodically examine with a hand lens the anthers of flowers at different stages of development in order to determine how late emasculation may be practiced without danger of selfing taking place.

In producing hybrid tomato seed on a small scale for breeding purposes or genetic studies, many workers have found it convenient merely to place a ripe anther tube from a male flower over the emasculated pistil of the female flower. This method has been considered

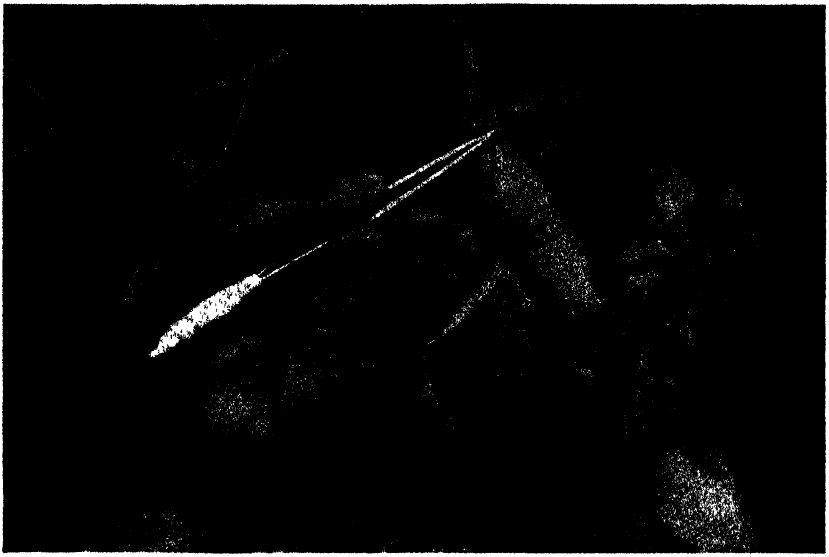

FIG. 1. First step in rapid emasculation. The base of two petals of a partially opened flower are grasped with forceps. (See Fig. 2.)

by some to be superior to placing pollen directly on the exposed stigma of the emasculated female, because it was thought that the anther tube afforded protection from contamination and prevented drying out of the stigma. It was found, however, to be more time-consuming than direct application, so a comparison of results obtained by the two methods was made. No appreciable difference was found in the percentage of fruit set or in the number of seeds per fruit. Furthermore, many of the anther tubes fell off due to the movement of the plant by wind. This test was conducted under conditions which were favorable for the setting of fruit, and is possible that under hot and dry atmospheric conditions the protection afforded the anther tube to the stigma might result in an improved set. However, in the balance of these experiments direct application of pollen was made because of the greater speed with which it could be carried out.

It is sometimes impossible to secure an abundance of ripe pollen from flowers immediately after they have been picked, especially on windy days. In order to avoid this difficulty, it was found desirable to pick male flowers each day and place them in a closed container kept humid by water or a moist absorbent material in the bottom to insure against wilting. After remaining in a cool place for 1 or 2 days, an abundance of pollen could be obtained from a majority of the flowers. For best results the flowers should be picked when fully opened but before the petals or anthers begin to discolor. In order to have an abundance of flowers for pollination, it is desirable to prevent fruit from developing on plants that are to be used as the male parent. This can best be accomplished by picking all of the open flowers every

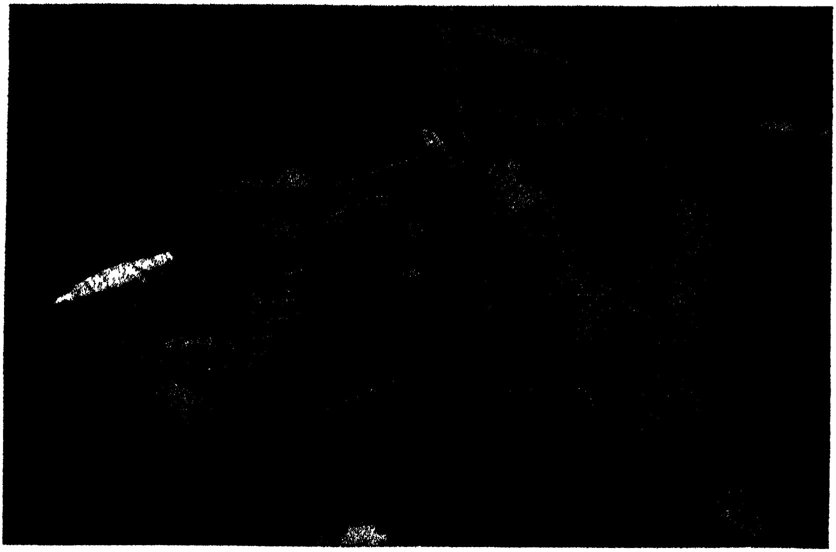

FIG. 2. Second step in rapid emasculation. A gentle pull removes the anther tube and corolla. (See Fig. 1.)

day. One male plant will produce sufficient pollen for at least 10 female plants.

It was found convenient to extract and apply pollen by means of

FIG. 3. Method of securing pollen. A flattened needle welded to the back of the forceps is used to remove pollen from the male flower.

a spear-shaped needle welded to the forceps as shown in Fig. 3. The anther tube of a male flower was first split at one suture and the pollen removed by running the point of the needle up the interior edges of the anthers. The pollen was applied by touching the pollen-laden tip of the needle to the stigma. Pollination may also be rapidly carried out by touching the pollen-laden interior of the anther tube to the stigma; however, if this method is used it is desirable to first release pollen from the ripe anthers by use of the needle.

The first blossom cluster was removed in most instances and pollination was started with the second cluster. Pollinations were made daily except during unusually cool weather when growth was very slow. By inspecting the plants at these frequent intervals few flowers passed the proper stage for emasculation, and those which did were immediately removed from the plant. Thus, all fruit which developed on plants in the crossing plot resulted from cross-pollination and no tags or other identification markers were necessary.

The question was raised early in the experiments as to the number of flowers that should be pollinated on each blossom cluster. Over a 2-week period as many pollinations as possible up to five were made on each cluster and the set of fruit was later recorded. These data are presented in Table I. It will be seen that under the conditions prevailing at the time of this experiment, a good set of fruit was obtained on the first, second and third flower to open on each cluster. A sharp drop was noted with the fourth flower and only a small percentage of the fifth flowers resulted in a fruit. On the basis of these data, it was decided to pollinate only three flowers per cluster and remove the rest. These were not always the first three to open as all abnormal blooms as well as those which had passed beyond the proper stage for emasculation were removed. This test was conducted early in the pollinating season when the plants were relatively small and during a period when weather conditions were conducive to a good set of fruit. Possibly later in the season when the plants might be at a lower nutritional level or when weather conditions were adverse, it would be desirable to pollinate only two flowers per cluster.

TABLE I—SET OF CROSS-POLLINATED TOMATO FRUITS ON DIFFERENT FLOWERS OF THE SAME CLUSTER

Flower No.	Per Cent Pollinations Resulting in Fruits
1	82
2	78
3	69
4	43
5	16

As flowers were emasculated as much as 24 hours before pollen ripened, a test was made early in the course of the experiments to determine whether the stigma was in a receptive condition at that time. Good results were obtained when pollinations were made immediately. Later a comparison was made of the set of fruit when pollination was carried out immediately upon emasculation and 1, 2, and 3 days thereafter. When pollinated immediately, 76 per cent of the blossoms set fruit, but a set of only 57 per cent was obtained when pollination was delayed until the following day. Even poorer results were obtained when pollination was delayed 2 or 3 days.

This is contradictory to the results obtained by Daskaloff (3). He found that pollination on the day of emasculation gave the poorest set of fruit (55 per cent) while a set of 75, 90, and 95 per cent was obtained from pollinations made on the first, second, and third days, respectively. Since Daskaloff carried out emasculation at the same stage of flowering as the writers did, there may be either climatic reasons for this obvious discrepancy, or conditions may differ according to the varieties. Preliminary studies conducted in 1941 seem to indicate that the latter assumption has some foundation. The period of receptivity of the stigma may be a varietal characteristic.

The question was raised as to whether an extra pollination on the day following emasculation and the first pollination would result in a sufficiently improved set to warrant the additional work involved. A comparison extending over a 10-day period was therefore made between the set obtained from once-pollinated and twice-pollinated flowers. An improvement in set of fruit of 12 per cent and in the amount of seed produced per pollination of 16 per cent was obtained by applying pollen on the day following emasculation and the first pollination. As so little extra time is involved in making this extra pollination, it was considered to be a worthwhile practice, and subsequent hybridization where cost records were kept was largely conducted on this basis. In actual practice pollination was carried out immediately upon emasculation and on any previously emasculated flowers whose stigmas remained a bright green. Thus, most flowers were pollinated a second and some a third time. However, as a rule, a browning of the stigma would begin to appear after 2 days and this was taken as an indication that no further pollination would be of value.

A limited test indicated there was no advantage with respect to the set of fruit obtained in confining pollination work to any particular time of the day. Some difficulty in keeping pollen on the needle was encountered during windy periods. As there tended to be less air movement in the early morning, much of the pollination work was conducted at that time.

Pollination was continued until six to eight clusters on each shoot or about 12 to 16 per plant had been used, and the plants were then topped. Pruning was carried out at the time of pollination as it was found to require very little extra time. Additional pruning at 10- to 12-day intervals was practiced in order to completely remove any lateral shoots missed by the pollinators.

POLLINATION RESULTS AND ESTIMATED COST OF PRODUCTION

An attempt was made to estimate the cost of producing hybrid seed over and above the cost of ordinary tomato seed by recording the time involved in making pollinations and the seed obtained. In addition, some observations were made on the set of fruit obtained during varying weather conditions. No very precise data are available, however, a few observations are presented here with the thought that they might prove of interest to one contemplating the production of hybrid seed.

In the first large scale test conducted in 1939 at Auburn, Alabama, 5.4 ounces of hybrid seed were obtained from 50 hours of pollinating. As a portion of this time was spent in developing technique, it was thought that even a greater amount of seed per hour might be obtained in later tests. It was observed that pollinations made on certain days resulted in a relatively high percentage of fruit set, whereas on other days a very poor set was obtained. In general, the hotter and the dryer the day, the poorer the results. These observations are not surprising in view of the work of Smith and Cochran (10), who showed that temperatures between 70 degrees F and 85 degrees F were optimum for pollen germination and tube growth. A marked decline in pollen activity was noted by these workers at temperatures of 100 degrees F. Temperatures above 90 degrees F were recorded on many days during which pollinations were made.

During a portion of the season a comparison was made of the results of hybridizing under an "aster" cloth shade vs hybridizing in the open. An increase in fruit set of 8 per cent was obtained under the shaded conditions. The conditions for the setting of fruit were good during this period and a shade might prove of even greater value under more adverse conditions.

On cleaning the seed, it appeared that the fruit resulting from cross-pollination had fewer seeds than fruit of the same size resulting from normal pollination. During the first year no data were obtained on the number of seeds per fruit.

In 1940 and 1941 the experiments were conducted at East Lansing, Michigan. Each year a crossing plot consisting of about 80 staked plants to be used as the female parent was grown. Data were obtained on the time involved in pollination and the results obtained in terms of fruit and seed harvested. These data are summarized in Table II.

TABLE II—TOMATO POLLINATION DATA FOR 1940 AND 1941

Matters Under Consideration	1940	1941
Total time involved in pollinating (hours)	50	57
Approximate number of pollinations made per hour	45	50
Per cent of pollinations resulting in fruit	40	55
Average number of seeds per fruit	43	36
Average number of seeds per self-pollinated fruit of variety used as a female parent	112	96

It will be noted that considering the season as a whole, 55 per cent was the best set of fruit obtained. It is perhaps even more significant that the number of seeds per fruit resulting from cross pollination was relatively small compared with the average number observed in normally pollinated fruits of the same variety. Again, as in 1939, it was observed that the results were much better than average during periods of moderate weather and much poorer than average during hot weather, especially when hot, drying winds occurred. During certain periods as high as 85 per cent of the pollinations set fruit. However, during no period did the number of seeds per fruit exceed 50 per cent of the average for the same variety when naturally pollinated.

Taking the two years as a whole, 107 hours of pollinating were required to produce 11.2 ounces of seed. If labor is calculated at 50 cents per hour, the pollinating alone would cost $4.86 per ounce. Other costs would be much higher than for ordinary tomato seed due to the comparatively low yield of seed per plant and the added cost of pruning and training. It is difficult to determine how much this would be, but 50 cents per ounce appears to be a reasonable estimate.

A number of different crosses have been made on a small scale in the greenhouse. Some of the hybridizing was carried out during March and April with plants started during December, and some during September and October with plants started in July. Unfortunately, detailed records were not kept of the number of crosses made and the percentage that set fruit. However, results were far better than obtained under field conditions.

One group of greenhouse pollinations of Bay State x Michigan State Forcing resulted in an 80 per cent set of fruit averaging 78 seeds per fruit. These pollinations were made in early October. Although pollinating costs would be considerably less under greenhouse conditions, actual production costs would probably be as high as under field conditions due to the expense of greenhouse operation.

DISCUSSION

It is obvious that unless seed production costs could be lowered, the widespread use of hybrid tomatoes for a field crop would be highly improbable. Growers might produce their own seed in a few instances but it is doubtful that seedsmen would care to enter into such an enterprise on more than an experimental scale. Tomato hybrids may have their greatest value for use in greenhouse production where returns per plant are relatively high. Even a 5 per cent increase in yield would far more than cover the added cost of producing hybrid seed. There appears to be no reason why greenhouse operators should not produce seed for their own requirements using greenhouse space for their hybridizing operations.

The observation that a better set of fruit was obtained during periods of mild weather than during the usual hot weather of late June and July when much of the pollinating was carried out, suggests that more efficient production might be attained where relatively cool summer temperatures prevail. The relatively uniform and moderate climate of certain areas on the Pacific Coast might prove favorable for such an enterprise. A California tomato seed specialist has been in correspondence with the writers and has conducted preliminary experiments on the possibilities of the commercial production of hybrid seed.

The questions of time of pollination in relation to time of emasculation, the number of pollinations that are profitable, and the best time of day in which to carry out the work should be studied in greater detail under climatic conditions especially favorable for the set of fruit. It is a common observation among tomato seed growers that varieties differ in the seed produced per given weight of fruit and likewise varieties differ greatly in the size of fruit. The efficiency of production could be increased whenever large fruited varieties that set seed freely under natural conditions could be used as the female parent.

The writers' observations confirm those of Daskaloff (3), who reported that it is immaterial whether a variety is used as the male or the female parent. The equality of reciprocal crosses is also in agreement with our present knowledge of genetics. According to Daskaloff (3), the French workers Alabouvette and Titard (1) found that reciprocal crosses produced hybrids differing in hybrid vigor, as measured by yield. The fact that they based their statements on experiments carried out with a rather small F_1 population might explain the contradictory results.

The report of Lesley and Lesley (8) on a male sterile tomato suggests the possibility of utilizing such a tomato as the female parent in the production of hybrid seed. The added cost of asexual propagation of the female line would no doubt be more than compensated for by the fact that emasculation and pruning and staking would not have to be practiced. Testing the F_1 hybrids resulting from crosses between available male sterile plants and desirable varieties would appear to be a worthwhile field for investigation.

The sale of hybrid tomato seed in trade packets, possibly containing about 1,000 seeds, would appear to be a desirable method of merchandising. The use of such seed would probably be confined to growers of a greenhouse or early market crop, and many such growers would not hesitate to buy expensive seeds since their acreages are usually small and their plant growing methods enable them to make the maximum use of all seed planted. If improvements in the efficiency of production were made, it is conceivable that a 1,000 seed packet might be retailed for as little as $1.00. Such a price would be far from prohibitive inasmuch as three to five packets would grow enough plants for an acre at customary field spacings. Tomato seeds average around 8,000 per ounce. To offer seed at $8.00 per ounce might invite failure because of the apparent high price, whereas $1.00 for 1,000 seeds would seem less costly to the grower.

SUMMARY

Experiments conducted over a 4-year period enabled the writers to develop a technique for producing hybrid tomato seed on an extensive scale. The various steps in the methods employed are described. The results obtained indicated that at best the production of hybrid tomato seed would be a costly enterprise and that comparatively high prices would have to be charged for the seed. If improvements along the lines suggested could be made, it is possible that such seed might be retailed for as little as $1.00 for a packet of 1,000 seeds. Considering the increases in yield that have been observed, both in the greenhouse and outdoor crop, there is no doubt that growers of early market and greenhouse tomatoes could afford this or even a higher price for seed. Some growers have already started to produce their own seed of certain hybrids and there appears to be no reason why this practice could not be extended in case the enterprise does not appear profitable to commercial seedsmen.

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The Possible Utilization of First Generation Muskmelon Hybrids and an Improved Method of Hybridization[1]

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IN the course of a muskmelon breeding program conducted by the Department of Plant Breeding of Cornell University for the purpose of obtaining a fusarium resistant variety satisfactory for New York State, the question as to the possibility of growing first generation hybrids commercially was raised by several melon growers. This was occasioned by an F_1 hybrid of Honey Rock and Plant Breeding No. 13. The latter is a fusarium resistant variety selected from material generously supplied by Professor T. M. Currence of the University of Minnesota and similar to Golden Gopher. The hybrid is fusarium resistant, of excellent appearance and quality, and apparently very productive. Although the fruit is rather small for present market preference, the hybrid appealed to several growers who saw it, and they inquired as to the possibility of producing it.

From information at hand concerning cost of pollination, it seemed that the cost of hybrid seed might not be prohibitive for Western New York growers who start their plants under glass and use only about 2,000 plants per acre. To determine how economically hybrid seed might be produced, and whether it has real advantages over open-pollinated varieties, were the objects of subsequent investigations reported here.

THE PRODUCTION OF HYBRID SEED

Curtis (1) has reported on the commercial production of F_1 hybrid seed of summer squash, and Hutchins (2) has suggested a similar possibility for cucumbers. Unfortunately from the standpoint of producing hybrid seed, the muskmelon differs from these other cucurbits in that most varieties are andromonoecious rather than monoecious in flowering habit, and an entirely different method of producing hybrid seed is necessary.

The usual method of making muskmelon crosses consists of emasculating perfect flowers the afternoon before the flowers open, bagging, uncovering the next morning, applying pollen of the desired male parent, and re-bagging.

The work of Poole and Porter (4), showing that high temperature inhibited pollen tube growth in the watermelon, suggested that in the muskmelon better sets of fruit might be obtained if pollination were followed by a cool period. This can be accomplished if pollination is done in the afternoon before anthesis and immediately after emasculation; but, since pollen in the field is not good after noon on most days, it is necessary to use pollen from male flowers picked in the morning and kept in a cool, moist place until used. Seventy-seven pollinations made in this way gave 55 per cent set of fruit, while forty-six pollinations made in the usual way gave only 41 per cent set, as shown in Table I.

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[1] Part of a thesis submitted to the Graduate School of Cornell University for the degree of Doctor of Philosophy.

TABLE I—RELATIVE SUCCESS OF CROSSES MADE IN THE AFTERNOON BEFORE ANTHESIS AND IN THE MORNING AFTER ANTHESIS

Date (1939)	Number of Pollinations	Per Cent Set	Time of Pollination
	Spencerport, N. Y.		
Jul 20	13	23	Afternoon
Jul 25	18	78	Afternoon
Jul 29	3	33	Morning
Jul 30	25	44	Morning
	Ransomville, N. Y.		
Aug 4	20	60	Afternoon
Aug 5	26	54	Afternoon
Aug 6	18	39	Morning
Total for morning (usual method)	46	41	———
Total for afternoon (improved method)	77	55	———

The most direct comparison is between August 5 and 6. The flowers pollinated on the afternoon of August 5 would have been pollinated with much less success on the morning of August 6, if the usual method of making crosses had been used for them.

It appears that under Western New York conditions, the afternoon pollination method is superior to morning pollination, although numbers are too small to be certain of this. At any rate, the new method gives as good results and requires much less labor since it makes unnecessary the finding of emasculated flowers, removal of bags, and re-bagging. These advantages seem to make feasible the production of hybrid seed for commercial use.

The statements which follow form the basis of an estimate of the cost of producing, by the new pollination method described, sufficient hybrid seed to plant an acre of muskmelons.

The majority of Western New York melons are started under glass. One method commonly used is to sow the seeds in flats and prick out the seedlings after about 8 days, one seedling per pot. By this means, only a few more seeds are required than the number of plants needed. Spacings of 6 by 4 and 6 by 3 feet are commonly used, requiring 1,815 and 2,420 plants per acre respectively. Under these conditions, about 3,000 seeds of good germination should provide enough plants for 1 acre.

This is admittedly the smallest amount of seed per acre which might be used. Most growers sow it much more lavishly. Nevertheless, one should expect to make the most economical use possible of seed produced by hand pollination.

As to the number of cross-pollinated fruits which would yield 3,000 seeds, it seems safe to say that 10 fruits would be the maximum needed. Ninety cross-pollinated fruits of Plant Breeding No. 13 produced an average of 337 seeds per fruit in 1940. This variety is small-fruited, and almost any other variety should produce as much seed.

The pollination cost for the 10 melons needed should not exceed one dollar, judging by sets obtained in Western New York for the last four years. At least 20 per cent of the cross-pollinations made for the season as a whole can be expected to set, and the average might easily be 25 to 30 per cent. Twenty pollinations can be made in an hour even by a rather inexperienced worker. Therefore, assuming labor at 40 cents an hour, 20 pollinations an hour, and 20 per cent set, 10 fruits could be hand-pollinated for one dollar. Adding another dollar to this for the cost of growing the melons, would bring to two dollars the total cost of producing enough hybrid seed for 1 acre.

Only a slight increase in yield, quality, or earliness would compensate for this seed cost.

PERFORMANCE OF MUSKMELON HYBRIDS

Four yield tests were conducted on soil not infested with fusarium at two locations in Western New York in 1939 and 1940 to compare several muskmelon hybrids with open-pollinated varieties. All hybrids had Plant Breeding No. 13 as one parent since a hybrid would have to be resistant to fusarium wilt to be of much use in this area.

The results given in Table II are from an experiment in Genesee County in 1939 in which three hybrids and five varieties were planted in 8 by 8 Latin squares, one plant per plot, spacing 5 feet each way, with duplicate squares side by side. Unfortunately, the Latin square design could not be utilized in analyzing the data because several plants were killed by bacterial wilt and mosaic. When a statement is made that a difference is significant, this means that "two-tailed" odds of 19:1 were obtained from the table given by Livermore (3).

TABLE II—TOTAL AND MARKETABLE YIELDS OF MELONS, EXPERIMENT II (GENESEE COUNTY, N. Y., 1939)

Variety	No. of Plants	Total Yield (Kilograms Per Plant)	Marketable Yield (Kilograms Per Plant)
1. Bender	14	2.96 ±0.41	2.78 ±0.32
2. Honey Rock	13	1.66 ±0.19	1 49 ±0.16
3. Weaver Special	13	1.35 ±0.17	1.08 ±0.15
4. P. B. 13	15	1.61 ±0.25	1.33 ±0.23
5. 13 ×Bender F_1	15	2.92 ±0.35	2.43 ±0.28
6. 13 ×Honey Rock F_1	15	3.14 ±0.29	2.33 ±0.31
7. 13 ×Weaver F_1	15	2.97 ±0.37	2.00 ±0.15
8. Queen of Colorado	15	2.43 ±0.30	1.83 ±0.21

In total yield Bender, Queen of Colorado, and the three hybrids form a group, all differing significantly from Honey Rock, Weaver, and Plant Breeding No. 13. None of the differences within either group is significant. In marketable yield the relation is about the same except that Queen of Colorado is significantly lower than Bender and not significantly higher than Honey Rock and No. 13. Also 13 x Weaver is significantly lower than Bender.

Thus we find that with the exception that 13 x Bender yields practically the same as Bender, the hybrids were higher yielding than either parent, and the differences were significant with respect to both total and marketable yields. The average of the hybrids was 58 per cent greater in total yield and 34 per cent greater in marketable yield than the average for the four parent varieties.

In an identical experiment in Niagara County, some of the susceptible plants were killed by fusarium wilt. From the remaining plants, yield differences were similar but not so significant as those above. Each hybrid produced greater total yield than either parent and, in four of the six comparisons, the difference was significant. In marketable yield, two of the three hybrids were better than either parent, but differences were not significant.

Two additional yield tests were run in Genesee County in 1940, and in one of them several new hybrids were included; namely, No. 13 crossed with Seneca Bender, Delicious, Queen of Colorado, and two Honey Rock inbreds kindly supplied by Dr. C. H. Mahoney of the University of Maryland. Briefly, the results were as follows: The average yields were much like those obtained in 1939, but standard errors were greater, and fewer differences between individual hybrids and varieties were significant. However, in one experiment designated as III, the combined yields of 13 x Honey Rock and 13 x Queen of Colorado were highly significantly greater than the combined yields of the two higher yielding parents — 37 per cent greater in total yield and 52 per cent greater in marketable yield.

In the other 1940 experiment, there was a highly significant difference between the six commercial varieties as a group and their hybrids with 13 as a group. The hybrids produced 42 per cent more in total yield and 36 per cent more in marketable yield than the varieties.

Considering the experiments as a whole, the hybrids as a group have yielded more fruit than either of their parents.

In addition to recording total and marketable yields of fruit, in Experiments II and III, the flesh was removed from all marketable melons, weighed, and the soluble solids in the juice determined by a Brix hydrometer. The weight of flesh in each fruit was multiplied by its Brix reading to obtain a value representing the relative amount of sugar in the flesh. It was thought that this would provide a rough estimate of the yielding ability of a variety in terms of the material essential for quality, *i.e.* sugar. Other factors such as aroma and texture undoubtedly influence quality of muskmelons, but up to a con-

TABLE III—YIELDS OF VARIETIES AND HYBRIDS EXPRESSED AS PERCENTAGES OF BENDER YIELDS

Variety	Total Yield of Fruit	Marketable Yield of Fruit	Marketable Yield of Flesh	Marketable Yield of Sugar	Average Brix Readings
		Experiment II, 1939			
Bender	100	100	100	100	9.92
Honey Rock	56*	54*	57*	67*	11.19*
Queen of Colorado	82	66*	69*	98	14.09*
P. B. 13	54*	48*	48*	55*	11.12*
Weaver Special	46*	39*	44*	56*	12.23*
13 ×Bender F_1	99	87	97	112	11.27*
13 ×Honey Rock F_1	106	84	97	123	12.45*
13 ×Weaver F_1	100	72*	81	107	13.50*
		Experiment III, 1940			
Bender	100	100	100	100	7.55
Honey Rock	55*	52*	55*	69	8.97*
Queen of Colorado	64*	74	93	150	11.88*
P. B. 13	48*	48*	52*	74	10.94*
13 ×Bender F_1	82	96	108	150*	10.38*
13 ×Honey Rock F_1	86	96	108	154	10.84*
13 ×Queen of Colorado F_1	78	95	110	187*	12.91*

*Significantly different from Bender with odds at least 19:1.

centration higher than is usually found in melons on the market, sugar is probably the most important factor influencing quality. The results obtained are summarized in Table III and expressed as percentages of Bender yields since Bender, because of its high yield of fruit, is the standard variety in New York State.

It is apparent that the comparison of the hybrids with their parents and particularly with Bender is much more favorable to the hybrids when yields of flesh and of sugar are considered. The hybrids generally yield about the same as or a little less fruit than Bender, but they produce a higher proportion of flesh and much more sugar in the flesh.

Curtis (1) found that in summer squash hybrids one manifestation of hybrid vigor was an increase in earliness in comparison with the parents. This is apparently true with muskmelons, although not so strikingly as with summer squash. The differences have not been large in most cases, but with only one exception each hybrid has produced more early fruit than either parent.

DISCUSSION

On the basis of the data presented concerning the cost of producing F_1 hybrid muskmelon seed and the performance of several hybrids, the commercial utilization of good hybrids appears possible when plants are started under glass and only a small amount of seed per acre is needed. As with other crops, not all hybrids are better than open-pollinated varieties, and it seems likely that better hybrids can be found than any of the few which have been tried so far.

However, yield and quality comparisons of muskmelon hybrids are more difficult and expensive than in the case of most other crops because of the large amount of space occupied per plant and the extreme variability produced by weather and diseases. It is doubtful whether an intensive search for good muskmelon hybrids is justified at present, at least in the Northeast. Here the quality and productivity of muskmelons seem to be limited by diseases more often than by the inherent capabilities of the varieties themselves. A more important objective at present would seem to be the production of acceptable varieties resistant to the more serious diseases.

Where disease resistance is dominant, hybrids may be especially useful in making acceptable disease resistant types available commercially before such types can be made relatively true-breeding by selection in the progenies of the hybrids. By crossing Plant Breeding 13 with Powdery Mildew Resistant 45, a hybrid has been obtained which is resistant to fusarium wilt and powdery mildew and of good quality and appearance. If both diseases were serious, this resistant hybrid might be made available to growers much sooner than a variety resistant to both diseases.

It is possible that the cost of hybrid seed may be reduced by developing monoecious strains to serve as female parents.

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Inheritance of Green Cotyledon in the Lima Bean

By Roy Magruder and R. E. Wester, *U. S. Horticultural Station, Beltsville, Md.*

Abstract

The detailed data of this investigation will be published in the *Journal of Agricultural Research.*

PRELIMINARY F_1 and F_2 data were reported on pages 581 to 584 in the 1940 Proceedings of the American Society for Horticultural Science. Additional F_2, F_3 and F_4 data corroborate the earlier conclusion that the green cotyledon character is a monogenic recessive to white or light cream-colored cotyledon.

Natural Self-Pollination in Cucumbers[1]

By J. Mitchell Jenkins, Jr., *South Carolina Truck Experiment Station, Charleston, S. C.*

THE amount of natural selfing in cross-pollinated plants such as corn, squash, or cucumbers is believed to be very low. Hayes (1) reported less than 5 per cent of natural self-pollination in corn. With muskmelons, according to Jones and Rosa (2), from 5 to 15 per cent of the seed of hermaphroditic-flowered varieties may be cross-fertilized, and a high percentage of cross-pollination is likely to occur in varieties having pistillate flowers. The cucumber is classed as a naturally cross-pollinated plant. It is monoecious, as a rule, and is pollinated by bees. One would expect a large amount of natural crossing between plants under these conditions.

Unlike corn and certain other cross-pollinated plants, cucumbers can be self-pollinated with little or no loss of vigor. According to Whitaker and Jagger (4), a number of investigators have shown that loss of vigor does not necessarily follow as a result of inbreeding squash, watermelon, or other cucurbits. Similar results were obtained at the South Carolina Truck Experiment Station where several varieties of cucumber were inbred for five generations. At the end of that time the inbreds were just as vigorous as commercial, open-pollinated stocks.

Correns advanced the theory (3) that monoecious forms arose from original hermaphroditic-flowered types. Assuming that the cucumber in its more primitive form was perfect-flowered, it is possible that it was largely self-pollinated unless anatomical defects or genetic incompatability prevented self-pollination. If normal self-pollination did occur it seems reasonable to assume that during the transition to the monoecious form of flowering the plant retained its self-fertility and enough dominant growth factors so that loss of vigor did not occur when plants were self-pollinated. There is also the possibility that enough natural self-pollination occurs in cucumbers to eliminate self-sterile plants as well as those lacking vigor. It was thought that the amount of natural selfing might be greater than the mode of pollination would indicate.

In March 1941 an experiment was set up to determine the amount of natural self-pollination in cucumbers under field conditions in South Carolina. Two inbred lines were used. One of them produced red colored mature fruits with black spines, while the other produced cream colored mature fruits and white spines. White spine color is a simple recessive to black spines and cream fruit color is recessive to red. Both dominant characters can be recognized easily in the F_1.

In one series of plots alternate rows were planted and seed was taken from 25 plants having the recessive characters, cream fruit and white spines. In another block 25 recessive plants were spotted at intervals so that each was surrounded by red-fruited, black-spined plants. Seed from the recessives was sown in August 1941 and counts were made of

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[1] Technical contribution No. 91 from the South Carolina Agricultural Experiment Station.

TABLE I—Results of Natural Crossing Tests with Cucumbers at the South Carolina Truck Experiment Station in 1941

Treatment	Number of Dominant Types	Number of Recessive Types	Percentage of Dominant Types	Percentage of Recessive Types	Percentage of Natural Self-Pollination
Adjacent rows (dominants on two sides)…………	334	681	32.9	67.1	33.5*
Individual plants (dominants on four sides)…………	81	44	64.8	35.2	35.2

*One-half the percentage of observed recessives (see text).

the number of dominant and recessive-type plants. The results are given in Table I.

In adjacent rows, spaced 6 feet apart, the amount of natural crossing between rows was 32.9 per cent. Therefore, about 67 plants out of 100 were either self-pollinated or were fertilized with pollen from other plants in the same row. The actual amount of self-pollination in this case was probably about one-half of the observed percentage of plants having the recessive characters, or 33.5 per cent. Where each recessive plant was surrounded by dominant plants on all four sides the amount of natural self-pollination was found to be 35.2 per cent. This agrees closely with the calculated 33.5 per cent in the first treatment.

On the basis of the results obtained, it may be concluded that as much as 30 to 35 per cent of natural self-pollination occurs in cucumbers under field conditions. This probably varies to some extent with weather and soil conditions and with different varieties since these are all factors which affect the ratio of staminate to pistillate flowers.

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Prevention of Field Hybridization in the Lima Bean

By ROY MAGRUDER and R. E. WESTER, *U. S. Horticultural Station, Beltsville, Md.*

IN VIEW of the large amount of field crossing in lima beans in Maryland (1) and the shortage of screened greenhouse space available for bean breeding, it was necessary to evolve a cheap method of producing selfed seed of bush lima beans in the field.

Following is a brief description of a method successfully used during 1940 and 1941 at the United States Horticultural Station at Beltsville, Maryland.

MATERIALS AND METHODS

A thin 28/20 mesh cotton plant-bed cover material 6 feet wide was used to cover the row of plants and was applied just before the plants started blooming.

The cloth was supported by wire wickets of No. 9 gauge galvanized steel wire. The wires were 6 feet long and were bent into a circular shape around a metal drum, with 6 inches at each end straightened out to form a peg. The wickets were spaced at about 4½-foot intervals, the "pegs" being thrust into the ground in shallow furrows made on each side of the row with a large wheel garden cultivator. The rows were 3 feet apart. The plants were thoroughly dusted with a derris dust containing ¾ per cent rotenone, to kill insects present.

In applying the cloth the proper length was first placed on the ground between two rows. One end (the "start") was securely tied to a stake at the end of the row. One side was then pulled up over the wire wicket and the cloth adjusted evenly. Three men worked together in keeping the cloth reasonably taut and in fastening it to the wickets with No. 2 safety pins. A safety pin was placed at the top of every wicket and on one side half way to the ground. The side pins were placed on alternate sides of adjacent wickets. The cloth was doubled over at pin insertion points to prevent tearing. The lower edge of each side of the cover was pressed into the shallow furrow and covered with loose soil along the entire length. By working together in this manner the entire operation was accomplished in one passage down the row without damage to plants or cloth by whipping of the cloth in the wind. Calm or quiet days are preferred. The "finish" end, like the "start", was anchored to a stake in such a way that the lower edges could be covered with soil as shown in Fig. 1.

The cloth is effective in excluding most insects until it rots along the bottom. This occurs in 3 to 4 weeks depending on weather conditions. The occasional bee that forces its way through a small hole or tear usually exhausts itself in trying to escape. It may be necessary to raise one edge of the cloth for the introduction of nicotine dust to control aphis.

As soon as the cloth in contact with the soil has disintegrated, the covering is removed. The youngest pods are then marked by tags or by daubing the raceme at their point of attachment with quick drying

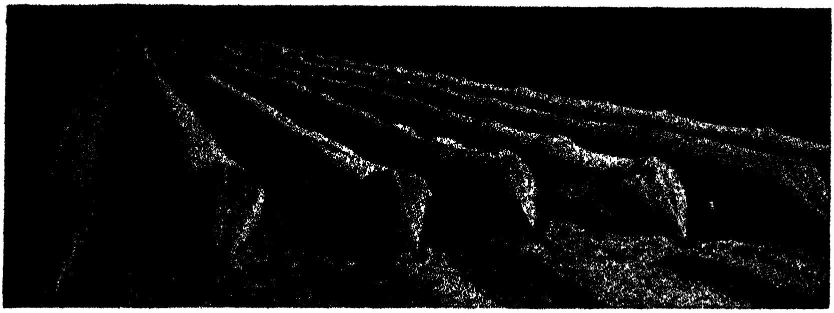

FIG. 1. Thin cotton plant-bed cover cloth used as an isolation material for bush lima beans. The cloth is supported on 9-gauge wire wickets and kept in place by soil along the lower edges and by pins at the wickets.

enamel. Pods which set beyond this point or after the cloth is removed are discarded.

RESULTS

Although no yield data were obtained it was evident that the set of pods on most families under the cloth was as good as, if not better than, on uncovered plants for the same time interval.

Shading did result in longer internodes and larger, thinner leaves but had no significant effect on pod or bean size or shape.

There was ample space for development of the Fordhook variety and more than was necessary for Henderson Bush lima.

The cloth can be used only one year for this purpose as the portion covered by soil rots and numerous holes are usually made in removing the pins.

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Plant- and Fruit-Pruning as a Means of Increasing Fruit Set in Muskmelon Breeding

By Emil A. Wolf and John D. Hartman, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

HAND pollination of muskmelon flowers ordinarily results in poor set of fruit. Seaton and Kremer (3), after working on cantaloupe breeding for a number of years, report that, on the average, only 5 to 10 per cent of their pollinations produced fruit. Burrell and Whitaker (1) state that 10 per cent represents the usual upper limit of successful hand-pollinations with this plant. Therefore, any improvment in breeding technique which can materially increase the percentage of fruit set is of value to the breeder in economy of time, effort, and expense.

It appears that a number of environmental and physiological factors influence fruit setting. Seaton and Kremer (3) found that temperature has a definite influence. Frazier (2) found that plants spaced 30 inches apart, in rows 6 feet apart, had a higher number of sets per plant than more closely spaced plants. Burrell and Whitaker (1) believe that the abscission of young fruits might in some way be related to the supply of a hormone-like or growth-promoting substance and were able to obtain 59 per cent fruit set by treating stigmas with indole acetic acid.

The junior author applied napthalene acetic acid to hand-pollinated muskmelons and watermelons in the greenhouse in July, 1938, without obtaining a marked improvement of set from these applications. However, he did develop a method of vine pruning which seemed to give a very decided increase in percentage of fruit set. In 1941 an experiment was designed to determine just how much pruning did affect set and to find whether the best method of pruning was being used.

PROCEDURE

Seeds of the New Seed Breeders strain of the Hale's Best variety were sown in hotbeds about April 10, 1941. At the end of 6 weeks, the plants were transplanted to the field and spaced 4 feet apart in 6-foot rows.

The six different pruning treatments eventually compared were as follows:

Treatment 1:—The flower pollinated was on a branch at least 2 feet long and at least four leaves from the base of the branch. No pruning of the plant was done before or after the pollination. All fruits other than the hand-pollinated one were kept pruned off the vines before the pollination and for 1 week after.

Treatment 2:—No pruning of the vine was done before the flower was pollinated. At the time of pollination, the terminal bud, other flower buds, and all axillary buds on the branch on which the pollinating was done were removed. The flower pollinated was on a branch at least 2 feet long and at least four leaves from the base of the branch. No other branches were pruned. All fruits other than the hand-pollinated one were kept pruned off the vines before the pollination and for 1 week after.

Treatment 3:—The plants were kept pruned to a single stem before and after pollination. This runner was at least 2 feet long and at the time of pollination all growing points and flower buds in the axils of the leaves for four leaves down the stem from the pollinated flower and for four leaves up the stem were removed. All fruits other than the hand-pollinated one were kept pruned off the vines before the pollination and for 1 week after.

Treatment 4:—Plants were kept pruned to one main branch and two axillary branches, from which the terminal buds and all growing points were removed. At pollination all growing points, flowers, and flower buds, except the flower which was pollinated, were removed. All fruits were kept pruned off the vines before the pollination. This is essentially the treatment developed by the junior author.

Treatment 5:—The plants were kept pruned to a single stem which was at least 2 feet long when the flower was pollinated. The flower pollinated was at least four leaves from the base of the branch and four leaves from the terminal bud. No pruning of the flower buds or terminal bud was done after pollination. All fruits were kept pruned off the vines before the pollination and for 1 week after.

Treatment 6:—No plant- or fruit-pruning whatsoever was used in this treatment. A flower was simply pollinated and none of the fruits were pruned off either before or after the pollination.

The degree of pruning practiced before and after pollination for these treatments is illustrated diagrammatically in Fig. 1. For most treatments the usual number of leaves per plant was much greater than is indicated in the diagrams. The plants of treatments 1, 2, and 6 became much larger than plants of other treatments, and those of treatment 4 somewhat larger than those of treatments 3 and 5.

Pruning, to make the plants conform to their proper treatments, was repeated weekly.

Twenty rows of 10 plants each were divided into plots of five plants each. On June 19 and 20 seven of these plots, systematically distributed over the whole area, were designated as belonging to treatment 1; seven others became replicates of treatment 2, seven of treatment 3, seven of treatment 4, and four of treatment 5. Treatments 1, 2, 3, and 4 were considered to be the most important ones. Treatment 5 was included merely to test the value of the removal of axillary buds as practiced in treatment 3. Although it is generally recognized that large melon fruits on a plant inhibit the set of new fruits, the senior author, after 2 days of pollinating, thought it advisable to add treatment 6 to serve as a rough check on this assumption. The eight plots of treatment 6 were incorporated into the experiment June 25.

Ten more plots, three of treatment 1, two of each of the treatments 2, 3, and 4, and one of treatment 5 were added June 28. These additional plots were also systematically distributed in rows not previously included in the experiment.

Hermaphroditic flowers were covered with a piece of ½-inch adhesive tape the evening preceding pollination. In the morning, the

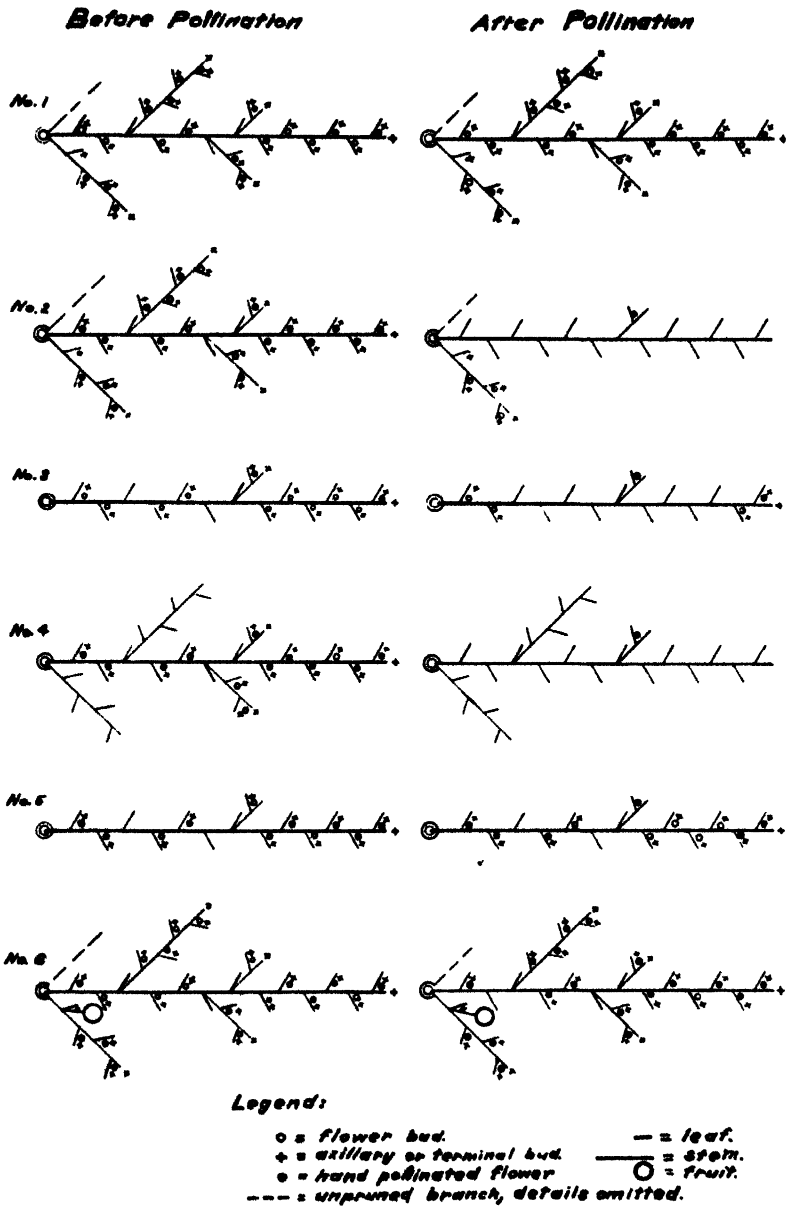

FIG. 1. Diagrammatic representation of pruning treatments.

corollas were removed with the tape and pollen transferred with tweezers to the stigmas. After pollination the pistil was again covered with tape and the flower labeled with a tag bearing the date, hour, and treatment. In order to retard the spread of mosaic and bacterial wilt, fingers, tweezers and the knife used in pruning were dipped in methyl alcohol before working on another plant. All pollinations were made between the hours of 5:00 and 9:30 a.m. To eliminate as far as possible any differences due to temperature, plants of several different treatments were pollinated in each hourly period. As nearly as possible equal numbers, at least one flower of each treatment, were pollinated each day. Pollination began on June 21, but was discontinued on July 1, because excessively hot, dry weather caused a scarcity of perfect blossoms. A heavy rain on July 2 brought about a drop in temperature and an increase in the number of perfect flowers. Pollinating was resumed on July 5 and terminated finally on July 13, when the total number of pollinations was 292.

In some cases when the fruit had failed to set on the plants receiving treatments 1, 2, 3, 5, and 6, a second pollination was made on the plants. In the case of treatment 4, no second attempts at pollination on the same plant were possible during the period of the experiment.

RESULTS

Results obtained from the 292 pollinations are given in Table I. Upon application of the Chi-Square test to these figures, as described by Snedecor (4), it was found that treatment 4 was significantly better than treatments 1, 2 and 6, at the 1 per cent point, and than 3 at the 5 per cent point; treatments 3 and 5 were significantly better at the 1 per cent point than 1 and 6. The difference between treatments 2 and 6 was highly significant and that between 2 and 1 significant.

TABLE I—EFFECT OF PRUNING TREATMENT ON SET OF FRUIT

Treatment No.	Summary of Plant Treatments	Number Set*	Number Failing to Set	Per Cent Set
1	Open pollinated fruits were kept pruned off the vines without pruning the plant itself	21	46	31.3
2	Open pollinated fruits were kept pruned off, and, at pollination, the branch on which a flower was pollinated was completely pruned	37	34	52.1
3	Open pollinated fruits were kept pruned off; plants were kept pruned to a single stem and at pollination growing points near the pollinated flower were removed	31	23	57.4
4	Open pollinated fruits were kept pruned off; plants were pruned to one main branch and two axillary branches; at pollination all growing points were removed	35	9	79.5
5	Open pollinated fruits were kept pruned off; plants were pruned to a single stem; no buds were removed at pollination	22	13	62.8
6	No plant- or fruit-pruning before or after pollination	3	18	14.3

*The figures in the third column include counts of fruits of four different classes: (a) fruits which matured seeds; (b) ovaries which were recorded as having set but which failed to develop to maturity because the plant died of bacterial wilt; (c) ovaries which were mechanically koocked off the vines, during soil cultivation, after being recorded as setting; and (d) fruits which rotted before maturity. There were only eight fruits, altogether, in the last three classes.

The pollinated flowers took about 4 weeks to develop into mature fruits; there were no differences between the six treatments as to the length of time required for the hand-pollinated fruits to develop.

The value of pruning fruits from the vines began to appear very soon after the experiment was started. Within a few days, perfect flowers became very scarce and hard to find on plants of treatment 6. For the most part, those which were found occurred on the smaller plants, on which there were as yet no sets. The ovaries of the few hermaphroditic flowers found on plants which had sets were mostly small, yellowish, and impotent. Also, in this treatment and in treatment 1 several flowers after pollination developed very slowly, but later shrivelled and dropped off the vines. Some of the fruits remained on the vines for 2 weeks or more and attained the size of walnuts before shrivelling and abscissing; others developed only slightly. On vines of treatment 6 some fruits which developed from naturally pollinated flowers that opened after a flower on the plant had been hand-pollinated grew normally and rapidly overtook the hand-pollinated fruits in growth. Likewise, open-pollinated flowers which set after the last fruit pruning, on plants of treatment 1, often rapidly outgrew and surpassed in development the hand-pollinated fruits.

DISCUSSION

The set on treatments 2 and 3, in comparison with that on treatment 1, appears to indicate the value of removing growing points and blossoms near the pollinated flower. On the other hand, results obtained with treatment 5 showed that good set is obtained merely by keeping down plant size, removing all actively growing branches before pollination, and leaving the terminal as the only meristematic region in anything like its "grand period of growth." Though the difference in favor of treatment 5 over treatment 3 is not significant, it seems to show that latent growing points did not exert any depressing effect on fruit setting; however, with treatment 4, in which the plant had no growing points of any kind, at least none but the very weakest, set was best of all.

The junior author has obtained an 80 per cent set by use of treatment 4 with watermelons as well as with muskmelons in both the field and greenhouse. During sunny weather, even higher percentages of set have been obtained with muskmelons in the greenhouse.

Although the difference in percentage of set between treatments 1 and 6 was not significant, treatment 6 demonstrated the value of fruit pruning in that, as the plants grew larger and set fruits, the hermaphroditic flowers became fewer and more difficult to find. During the period of the experiment, it was possible to do only one-third as many pollinations on plants of treatment 6 as on plants of treatment 1.

It is estimated that the total amount of time required for pruning plants, finding flowers, and pollinating them, was roughly about 20 to 25 minutes per plant for treatment 4. This was less than the amount of time spent in searching for blossoms on plants of treatment 6 and only slightly more than the time spent in searching for blossoms on plants of treatments 1 and 2. Treatment 5 required the least total amount of time; treatment 3, slightly more; and treatment 6 most.

The chance to pollinate a plant of treatment 4 is usually not lost if the first attempt fails. Although it was not possible to make a second attempt at pollination during the period of the experiment on plants on which the pollinated flower had failed to set, most of the plants had started to develop small new branches, and within a short time another attempt could have been made. It might be well, in case of plants which appear to be exceptionally valuable, to leave some very small visible growing points intact. In fact, treatment 4 is particularly adapted, under many circumstances, to provide reasonable assurance that seed may be obtained from an individual plant which has already proven its worth in the field.

SUMMARY

Six different fruit- and plant-pruning treatments were tried and a total of 292 pollinations were made over a period of 23 days. Treatment 4 in which the plants were completely pruned gave best results; 79.5 per cent of the pollinated flowers set fruits. This percentage is several times greater than the 5 to 10 per cent set obtained by Seaton and Kremer (3) in their work with cucurbits and larger than that obtained by Burrell and Whitaker (1) by use of indole acetic acid.

Fruit-pruning had a noticeable influence on the number of available hermaphroditic flowers produced by the plants. Flowers on completely unpruned plants became very hard to find as the plants grew larger.

Pruning treatments seemed to have no particular influence on the length of time required to produce a mature fruit. Fruits matured in about 4 weeks from the time flowers were pollinated.

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The Relation of Leaf Structure to Thrips Resistance in the Onion

By C. E. Peterson, *U. S. Department of Agriculture,* and
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Abstract

The complete paper will be published as a bulletin of the Iowa Agricultural Experiment Station.

MEASUREMENTS of freehand sections of onion leaves showed a greater thickness of epidermis on thrips-resistant plants than on susceptible plants. Thickness of epidermis varied in different positions on the same leaf as well as between leaves of the same plant. Varietal differences were greater for more mature leaves than for the younger center leaves. On nearly mature leaves the average thickness of epidermis of White Persian, a very resistant variety, was found to be greater than that of susceptible Scott County Globe plants. Differences in this case were very highly significant. White Persian was also observed to have a significantly greater epidermal thickness than Sweet Spanish, a variety which is intermediate in resistance to thrips. Statistically significant differences between Sweet Spanish and Scott County Globe were observed in only two of nine positions sampled, although in every case the average thickness of epidermis was greater on Sweet Spanish than on the corresponding leaf-position mean for Scott County Globe. In contrast to the results from freehand sections, the data from measurements of permanent mounts showed a significant difference between these two varieties. This discrepancy might be attributed to greater accuracy in measurement which was possible with permanent mounts.

The epidermis on mature leaves of White Persian was thicker than that of either Scott County Globe or the F_1 hybrid from the cross Scott County Globe x White Persian. No significant difference was observed between Scott County Globe and the hybrid. Very little difference in resistance to thrips was observed between the hybrid and the susceptible parent.

A thick epidermis probably reduces thrips damage by offering greater mechanical resistance to puncturing and by limiting the depth to which the thrips stylets can penetrate the leaf tissue. Smaller thrips populations that have been observed on resistant plants may be the result to some extent of a thicker epidermis. Migrating adults probably do not remain on such plants because the food supply is not easily available. The thickness of the epidermis on young center leaves of resistant plants may be no greater than on mature leaves of susceptible plants. Thus a small portion of the total leaf area of a resistant plant may be as vulnerable to attack as a susceptible plant. However, in these young leaves the cells are enlarging rapidly and soon attain what might be termed protective proportions. Furthermore, as suggested above, a thick epidermis on the mature leaves of the plant may serve to restrict the population of thrips on the more vulnerable center leaves because the migrating adults do not remain to propagate. The presence of normal, undamaged leaves would also help to maintain proper physiological conditions for the formation and rapid growth of new leaves.

The depth of the palisade layer in leaves of White Persian was greater than that of either Scott County Globe or Sweet Spanish. The differences in favor of the White Persian were greater in the more mature leaves than in the center leaf. No significant differences were observed between Sweet Spanish and Scott County Globe.

The varietal differences observed in the measurements of depth of vascular bundles were found to closely parallel those of the palisade layer. There were no significant differences between Sweet Spanish and Scott County Globe, but greater depth was observed in White Persian than in either Sweet Spanish or Scott County Globe.

Total thickness of the more mature leaves of White Persian was greater than that of either Sweet Spanish or Scott County Globe. The outer or more mature leaves of Sweet Spanish were also significantly thicker than those of Scott County Globe. No significant varietal differences in leaf thickness were observed in comparing the young center leaves.

The thicker leaf tissues observed in resistant plants probably have the effect of preventing rapid dessication of thrips-injured leaves. Since the initial feeding injury is less severe on the resistant plants the importance of this character is difficult to evaluate.

Nematode Resistance Test of Tomatoes

By F. A. ROMSHE, *Oklahoma Agricultural Experiment Station, Stillwater, Okla.*

FIELD trials of tomatoes to determine if any species or varieties are resistant to the root-knot nematode, *Heterodera marioni* (Cornu) Goodey, were started in the spring of 1940. The soil in which the plants were grown was heavily infested due to continued production of susceptible vegetables for a period of years.

Ten plants each from 550 lots of seed were set out. The seed for 390 lots were introductions from South America by the Bureau of Plant Introduction and supplied by Dr. H. L. Blood of the Utah Experiment Station. The other lots were furnished by various tomato breeders and seed companies. The three species *Lycopersicon esculentum, L. peruvianum, L. pimpinellifolium,* and some varieties developed from crosses of *L. esculentum* x *L. pimpinellifolium,* and *L. esculentum* x *L. chilense* were included in this group.

No results were secured in 1940 due to the almost complete absence of nematode infestation on the test plants, despite the fact that the tomatoes were allowed to grow in the field for a period of 5 months. The marked reduction in nematode population in the soil of the test plot was very likely due to an extended hot dry period the previous fall, which dried out the soil of this plot to a depth of several inches. Soil in adjacent plots on which fall crops were grown with irrigation in 1939 are still infested.

The test in 1941 was made on an area which became uniformly and heavily infested with nematodes while being devoted to sweet potato production. This area had been planted to Lima beans for 4 years previous to 1941. The bean plants were very heavily infested with nematodes in 1940. Plots of 10 plants each of 221 lots of tomatoes were set in the field in May. The plots were placed at random throughout the experimental area. These plants were dug in July and the roots examined for nematodes. Nine lots of *Lycopersicon peruvianum* were entirely free of root-knots and the other lot of this species planted had only a very light infestation. Ten plants of husk tomatoes, *Physalis pubescens,* were also practically free from nematode injury. Plants of the other 210 lots of tomatoes were quite heavily damaged. The fact that each lot of *L. peruvianum* was bordered on each side by plants which became heavily infested with nematodes seems to justify the conclusion that this species has considerable root-knot resistance. These results are in agreement with those reported by Bailey (1).

The use of *Lycopersicon peruvianum* as breeding stock to develop commercial varieties of tomatoes with nematode resistance appears possible at the present time. It is understood that several workers have obtained crosses of this species with *L. esculentum.*

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Heat and Drought Tolerance of Sweet Corn as Influenced by Tillers

By S. A. McCrory, *South Dakota Agricultural Experiment Station, Brookings, S. D.*

THE material presented in this paper is from data obtained while conducting a sweet corn breeding project. The primary object of the work is to develop a plant tolerant to high temperature and drought conditions.

Excessive tillering was observed on many hybrids and open pollinated varieties in 1939. Moisture was abundant, and temperatures were not abnormally high during the growing season. Many tillers produced ears. In general the percentage of marketable ears was inversely proportional to the number of tillers. This invited some investigation as to how the heat and drought tolerance of the main stalk is influenced by tillers.

Literature Review

Results of tiller studies (1) with field corn show that by removing the tillers the yield is reduced 17 bushels per acre during years of plentiful rainfall. Earlier work (2) at the same station obtained similar results during periods of ample moisture. However, it was the opinion of the worker that on poor soil or during a series of dry years the results might have been different. Other data (3) collected from sweet corn studies indicate that removing the tillers reduces the number of marketable ears although the decrease in yields is not significant except in the case of late tiller removal. From the same report it was interesting to note that on two consecutive years Golden Bantam produced a greater yield where the tillers were removed early in the growing season. The reverse was true for the next two years. With Stowell's Evergreen there was less difference in yield, as influenced by treatment, than with Golden Bantam.

Thus the literature suggests that in general the absence of tillers is actually detrimental to production. It is logical to assume that with less soil moisture, a low relative humidity, high temperatures and greater wind velocity, a variety with few tillers might be desirable.

Method and Climatic Conditions

In 1940 sixty-six of the more common sweet corn hybrids were planted. Duplicate plantings of 20 hills each were made. The hills were spaced 42 inches with similar spacing between rows. A space equal to the width of a row was left between each planting to reduce mechanical injury when the workers were removing tillers. This did not give as many plants per acre as would normally be planted. Tillers were repeatedly removed from half the hills as soon as they appeared.

Rainfall was abundant except for a short period near the end of the growing season. The temperature was not excessively high for long periods and reached 100 degrees F on only two days.

These hybrids could be placed in three groups according to the time tillers appeared. They were classed as early, midseason, and late. They also differed in the number of tillers per plant. Their appearance date showed no positive correlation with date of ear maturity. Those hybrids with tillers not developing at a definite period were not considered. In general there were no apparent differences in these hybrids as influenced by the presence or absence of tillers. Data on yield and growth habits are summarized in Table I.

TABLE I—AVERAGE YIELD AS EXPRESSED IN PER CENT OF MARKETABLE EARS, NUMBER OF EARS PER HUNDRED PLANTS AND POUNDS OF CORN PER ACRE

	No. of Samples*	Per Cent of Marketable Ears	No. of Ears Per 100 Plants	Pounds of Corn Per Acre
F-L†	9 O	74	120	2340
	9 X	87	163	2548
M-E	3 O	87	152	2457
	3 X	80	197	2620
M-Ms	27 O	85	170	3366
	27 X	86	165	3316

†F-L—two tillers per plant appearing late in the season. M-E—3 to 4 tillers per plant appearing early. M-Ms—3 to 4 tillers per plant appearing near the middle of the growing season.
*O—tillers on.
X—tillers removed.

The data in Table I suggests that in general the removal of tillers did not reduce yield when averages are considered. The number or date of appearance or both may be of importance.

TABLE II—PLANTS HAVING 1 TO 2 TILLERS DEVELOPED LATE IN THE SEASON

Variety	T*	No. of Ears Per 100 Plants	Per Cent Marketable Ears	Pounds of Corn Per Acre	Resistance to Pull
909×870	O	210	95	5469	203.1
	X	218	79	4253	228.9
880×870	O	200	90	4156	
	X	205	87	4393	
880×22	O	195	80	3172	
	X	200	71	3451	
41×43	O	200	97	4463	199.5
	X	200	97	4327	207.1
888×909	O	172	93	3914	208.5
	X	164	75	3193	171.3
42×41	O	206	76	4060	224.4
	X	194	69	4564	184.6
42×43	O	279	84	3906	185.0
	X	181	93	3066	175.9
42×908	O	245	85	4849	138.3
	X	171	63	4063	123.7
42×881	O	211	81	4249	235.7
	X	180	86	3631	226.7
891×909	O	126	88	3197	147.3
	X	137	77	3312	190.4
891×42	O	206	67	3307	231.2
	X	188	82	3234	184.9
43×42	O	156	88	3778	
	X	184	83	4001	
885×42	O	158	77	3611	
	X	145	72	2713	
908×883	O	216	85	4232	146.4
	X	200	86	4474	160.9
883×908	O	194	88	4376	
	X	153	89	3588	
Mean	O	198.2	84.9	4049.2	191.9
	X	181.3	80.6	3750.8	185.4
Odds	—	31:1	16:1	31:1	3:1

T*—Tillers; O—On; X—Off.

METHOD AND CLIMATIC CONDITIONS, 1941

In 1941 many samples of sweet corn hybrids were planted. These came from inbred lines showing heat and drought tolerance. The same planting plan was followed as used in 1941 except that duplicate plantings were not made. Failure to get extreme heat and drought conditions the previous seasons discouraged extensive planting. Early in the season it became apparent that heat and drought would be limiting

TABLE III—SAMPLES HAVING 3 TO 4 TILLERS PER PLANT DEVELOPED DURING MIDSEASON

Variety	T*	No. of Ears Per 100 Plants	Per Cent Marketable Ears	Pounds of Corn Per Acre	Resistance to Pull
909 ×22	O	145	75	3391	198.5
	X	288	83	6540	149.6
909 ×888	O	223	68	4708	135.1
	X	187	86	3911	133.7
22 ×909	O	272	79	5349	129.2
	X	228	80	4546	128.3
22 ×41	O	150	87	3281	232.5
	X	220	86	4309	199.5
880 ×42	O	206	83	4109	222.1
	X	153	89	3220	190.4
880 ×41	O	183	67	3696	
	X	200	67	3354	
880 ×908	O	200	91	5008	
	X	200	100	4425	
880 ×909	O	185	73	4463	240.3
	X	172	83	3890	184.9
41 ×881	O	215	76	4900	228.9
	X	194	90	4120	232.5
41 ×909	O	170	76	3916	187.2
	X	173	69	4057	184.9
41 ×880	O	184	88	3542	180.4
	X	179	76	3312	189.5
888 ×908	O	150	73	2888	
	X	150	66	2756	
42 ×22	O	221	80	4784	215.3
	X	232	79	5106	223.5
891 ×22	O	185	86	4003	
	X	175	83	3828	
908 ×885	O	206	94	4764	224.4
	X	200	89	4531	175.9
908 ×881	O	200	72	4435	
	X	189	89	4577	
908 ×880	O	205	92	4288	
	X	206	90	4462	
908 ×41	O	189	91	4741	242.5
	X	139	92	352.5	210.8
908 ×42	O	150	89	2918	
	X	228	75	4250	
908 ×22	O	193	86	4466	
	X	209	70	4174	
908 ×43	O	195	77	4303	181.3
	X	173	84	3910	142.8
908 ×870	O	168	78	4002	
	X	176	80	3991	
908 ×884	O	225	84	4550	160.0
	X	179	79	3634	137.3
908 ×886	O	200	82	5336	278.8
	X	163	80	4709	214.4
908 ×894	O	194	86	4623	216.7
	X	189	88	4401	191.7
881 ×41	O	147	80	3013	
	X	230	83	4842	
886 ×909	O	145	86	3938	175.9
	X	106	84	2845	217.6
886 ×908	O	211	888	5175	
	X	184	83	4669	
Mean	O	189.9	81.7	4235.4	202.9
	X	190.7	82.3	4139.1	182.8
Odds	—	None	2:1	2:1	216:1

T*—Tillers; O—On; X—Off.

factors of plant growth so tillers were removed from half the plants in each sample.

Extremely high temperatures were recorded from July 7 until early August. The average daily maximum for the period was over 100 degrees F with the extreme of 108 degrees reached on two days. There was a deficiency of soil moisture with the relative humidity during mid-day ranging from a low of 37 per cent to a high of 49 per cent for the 2 weeks period. The peak of the tasseling period for most varieties came near the beginning of the severe heat. Tables II, III, and IV, group the samples as to the number of tillers per plant and also the date they appeared. Tillers were removed from half the plants. Mechanical injury was very slight because of the small size of the tiller removed. After harvesting the ears, a pulling device was used to measure the resistance of a hill to a pulling force. Eight hills were pulled from each sample, four of which had the tillers removed. The average for the four was considered as representative.

TABLE IV—PLANTS HAVING 3 TO 4 TILLERS PER PLANT DEVELOPED DURING THE EARLY PART OF THE SEASON

Variety	T*	No. of Ears Per 100 Plants	Per Cent Marketable Ears	Pounds of Corn Per Acre	Resistance to Pull
909 ×43	O	169	77	3531	120.1
	X	182	74	3605	135.1
909 ×880	O	212	88	4867	157.7
	X	200	86	4474	147.3
909 ×23	O	215	76	4200	157.7
	X	188	80	3559	140.5
22 ×891	O	200	97	4300	135.1
	X	200	73	5616	134.6
22 ×880	O	161	82	2723	139.6
	X	144	73	2261	123.3
880 ×43	O	237	76	4485	
	X	237	84	3979	
880 ×885	O	156	89	3914	301.4
	X	190	87	4550	301.4
880 ×881	O	237	73	3864	
	X	241	90	4403	
892 ×908	O	—	—	—	204.0
	X	—	—	—	230.3
891 ×41	O	200	88	4747	265.2
	X	185	81	4375	257.5
908 ×23	O	215	93	4506	121.5
	X	233	78	4425	139.6
882 ×909	O	167	90	4182	
	X	163	84	4094	
890 ×908	O	205	87	4660	290.1
	X	210	80	4922	231.2
886 ×880	O	255	88	5447	203.1
	X	205	94	4508	205.3
887 ×908	O	170	74	3106	
	X	189	70	3795	
881 ×23	O	172	90	3574	
	X	200	72	3719	
882 ×908	O	170	70	3609	
	X	200	82	4807	
Mean	O	197.1	84.0	4141.5	190.5
	X	196.6	80.4	4099.4	186.0
Odds	—	3:1	10:1	2:1	3:1

T*—Tillers; O—On; X—Off.

It will be noted that in Table II the number of ears per hundred plants were reduced where tillers were removed. There was also a reduction in the acre yield. Here they appeared late in the growing period. In no other case was there a difference great enough to indicate statistical significance. The resistance to a pulling force was greatest when 3 to 4 tillers per plant appeared at the middle of the growing season. The difference in the force required to pull the plant indicates significance with odds 216 : 1. These tillers were making their greatest growth immediately before the drought conditions started.

Top Firing

During the middle of the day much rolling of leaves occurred. This was accompanied by firing of the tassel and in many cases the top leaves as well. Top firing was noticeably worse on the plants with tillers (see Fig. 1). Rolling of leaves also occurred earlier in the day on the tiller bearing plants. In extreme cases every plant showed top firing when tillers were present, but no plant showed firing in adjacent rows where the tillers had been removed. Yield did not appear to be reduced by top firing but such plants were dependent on others for pollen.

Fig. 1. Effect of tiller on top firing. Tillers removed from plants on the right, with normal tillering on the adjacent row.

On August 1, 35 per cent of the plants described in Table IV showed some top firing, 33 per cent for those found in Table II, and 14 per cent for those described in Table III.

It is not intended to suggest removing the tillers from sweet corn. It seems possible to develop a hybrid with few or many tillers. This report is of a preliminary nature and results are not conclusive. Early results indicate that, all other things being equal, the period when tillers develop is as important to heat and drought tolerance as are the number that appear.

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Sugar Content of Sweet Corn Pollen and Kernels of Inbred and Hybrid Strains Susceptible to Tassel Infestation by Aphis[1]

By E. S. HABER and W. G. GAESSLER, *Iowa Agricultural Experiment Station, Ames, Ia.*

IT HAS been observed by sweet corn breeders that the tassels of some inbred lines of sweet corn are more heavily infested with aphis than others. Lines have been developed in which all of the plants will have the tassels infested with aphis while all or nearly all plant tassels in a resistant line will be free of aphis under the same conditions. In sweet corn growing areas where high humidity prevails, the infestation may be so heavy that pollen shedding may be prevented from heavily infested plants. It has been reported to the authors that the tassels of Iowa golden inbred line 45 may be so heavily infested in the New England states that little or no pollen is shed. Likewise in Iowa this line shows a high degree of susceptibility to aphis infestation, the infestation being sufficient to reduce but not prevent shedding of pollen. The development of hybrid sweet corn strains from aphis-susceptible inbred lines is not advisable because of the possibility of poor pollination. If the aphis infestation occurs at the right time, poor pollination may render hybrid sweet corn valueless for market or canners.

The assumption is frequently advanced that high sugar content of the pollen in susceptible lines attracts the aphis. It is also frequently assumed that the high sugar content of the pollen is associated with high sugar content of the kernel. The investigation reported in this manuscript was undertaken to test these two assumptions.

In 1941, a number of inbred and hybrid lines were grown which were known to be highly or partially susceptible to aphis injury in the tassels for analysis of pollen and kernels.

Samples of pollen were obtained by cutting 12 or 15 tassels of each strain when about one-third of the anthers had dehisced and placing the stems immediately in a jar of water. The jars of tassels were taken to the laboratory and placed on glazed paper after shaking to dislodge dead and foreign pollen adhering to the tassels. Several hours later the tassels were jarred again to dislodge the pollen; these pollen grains were used for analysis.

The pollen contained more moisture when samples were taken by shaking the tassels rather than allowing them to stand and gathering the pollen which dropped naturally to the glazed paper. In general the moisture content of the pollen was higher than that reported by Miyaki (1) on dent corn who used the latter method. When tassels were allowed to stand in the laboratory for various lengths of time before shaking to dislodge the pollen, little difference in moisture content of the pollen was found until the tassels began to dry up, usually within 4 days. The percentage of moisture in sweet corn pollen taken at various time intervals was as follows: 6 hours (56.92); 6 hours (56.85); 24 hours (54.16); 24 hours (55.33); 24 hours (54.37); 20 hours (27.86). The same tassels of inbred C15 were used for the preceding determinations. In about 4 days the tassels began to dry up and the moistrue content of the pollen was very low as indicated in the last column. The laboratory temperature was 24 to 29 degrees C and the humidity between 60 and 75 per cent.

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The collected pollen was screened through a 60-mesh sieve to remove the anthers. The pollen was dried in a 60 degree C vacuum oven for 16 hours. A current of air was passed continuously through the oven. The ether extract of the pollen was determined on a 2 to 3 gram sample in a Bailey-Walker apparatus for 16 hours with 25 cubic centimeters of anhydrous ether. The drying and weighing of the extracted material continued until a constant weight was reached.

The nitrogen determinations were made according to "Official Methods" of the A.O.A.C. and the sugars by the Shaffer-Somogyi (3) method.

For moisture determinations of the kernel, 20 gram samples were placed in a vacuum oven at 70 degrees C, with a large volume of air continuously passing through the oven. Weighings were made at convenient intervals until constant weight was reached. For sugar determinations, 20 grams of the fresh kernels were transferred into a 250 cubic centimeters Erlenmeyer flask, 100 cubic centimeters of 95 per cent alcohol was added, the corn was crushed with a blunt instrument and the flask was placed under a reflux condenser in a 65 degree C water bath for 1 hour. The material was filtered and washed with 80 per cent alcohol, then the alcohol solution was evaporated almost to dryness at 70 degrees C. After making up to volume with water, clearing with neutral lead acetate, deleading with sodium oxalate in the usual manner, reducing sugars were determined before and after hydrolysis by the Shaffer-Hartman (2) method.

In Table I it can be seen that there is little difference between the strains of corn as regards nitrogen and ether extract. Even the pollen of dent corn strains. Os 426 and Os 420, contained approximately the same amount of these materials as did the sweet corn strains.

The percentage of total sugars present, varied in the various lines but there was no correlation between aphis susceptibility and the amount present. The pollen of Os 420 and Os 426, both dent corn, contained about as much sugar as the highest sweet corn strain. Inbred 45, a highly aphis susceptible sweet corn strain, contained relatively low sugar content in the pollen whereas the green corn contained a relatively high amount of sucrose and total sugar. Strain 7, an aphis resistant strain had 12.9 per cent total sugar and 10.4 per cent sucrose in the pollen, while the green corn contained 8.6 and 7.5 per cent respectively.

In conclusion, it may be stated that under conditions at Ames, Iowa in 1941, tassel infestation by aphis is not the result of high sugar

TABLE I—CORN POLLEN AND GREEN CORN DETERMINATIONS

Sample No.	Percentage Oven-Dry Basis (Pollen)						Percentage Oven-Dry Basis (Green Corn)			
	Water	Reducing Sugars	Sucrose	Total Sugars	Nitrogen	Ether Extract	Water	Reducing Sugars	Sucrose	Total Sugars
C15	55.0	0.8	13.2	14.0	3.39	0.9	69.2	1.3	5.9	7.2
C25	50.0	1.4	12.8	14.2	3.63	1.1	70.4	1.2	6.8	8.0
Whipple's Yellow	57.6	1.3	11.7	13.0	3.33	1.0	62.7	0.7	6.1	6.8
C87 ×C81	48.0	6.6	7.9	14.5	3.70	0.9	77.4	1.6	8.4	10.0
H2	59.6	4.7	3.8	8.5	3.46	1.0	71.3	1.8	6.8	8.6
45*	60.8	6.7	3.3	10.0	3.95	1.0	72.7	2.3	9.0	11.3
C7* ×C53	60.0	6.5	3.5	10.0	3.69	1.1	70.2	1.3	3.0	4.3
No. 7‡	52.9	2.5	10.4	12.9	3.35	0.8	67.5	1.3	7.5	8.6
C87	58.8	4.0	6.5	10.5	3.40	0.9	74.9	2.0	10.8	12.8
WR No. 7	55.7	4.8	6.6	11.4	3.80	0.9	69.4	1.6	3.8	5.4
Os. 426*†	55.5	2.0	12.7	14.7	3.98	0.9	70.2	1.0	1.4	2.4
Os. 420*†	28.2	3.1	11.2	14.3	—	0.9	76.0	1.6	1.4	3.0

*Aphis susceptible.
†Dent corn
‡Aphis resistant.

content of the pollen nor is the sugar content of the pollen correlated with sugar content of the kernels at the edible stage. It is possible that analyses of the anthers or total tassel tissues might throw further light on the matter.

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A Comparison of the Chemical Composition of Artificially Produced Parthenocarpic Fruits and Normal Seeded Fruits of Peppers[1]

By BYRON E. JANES, *A. & M. College of Texas, College Station, Tex.*

IN a previous report the author (5) showed that there were differences in the carbohydrate and acid contents of parthenocarpic and seeded tomato fruits. The parthenocarpic fruits had a higher percentage of carbohydrate than the seeded fruits. This difference was mainly in the locular region. The titratable acid of the parthenocarpic fruits was only slightly lower than that of the seeded fruits; however, the distribution of acid was different in the two types of fruits. The titratable acid was approximately the same in the different regions of the parthenocarpic fruits, but it was much higher in the locular region and lower in the pericarp of the seeded fruits than the average for the entire seeded fruits. This report deals with similar studies made on parthenocarpic and seeded pepper fruits.

MATERIALS AND METHODS

Fruits of *Capsicum annuum* variety California Wonder, grown in the field at the University of Michigan Botanical Garden, were used in these experiments. Parthenocarpy was induced by the method developed by Gustafson (1), using 1 per cent indole butyric acid in lanolin as the stimulant. Each day that flower buds were treated with indole butyric acid the same number of blossoms which had already opened were pollinated and labeled for controls. Parthenocarpic and seeded fruits to be compared were picked at the same time. They were picked from the same plant or from similar plants growing close together.

Pepper fruits do not all ripen at the same age, so that it is necessary to have some other criterion than age as a measure of their maturity. Color, which was used as a measure of ripeness in the tomato studies, proved very satisfactory in these investigations as well. For the more immature fruits, however, the age served as a good indicator of the physiological state. Samples of the following stages were obtained: 15-, 33-, and 47-day-old fruits harvested according to age; dark green, averaging 58 days old; green with some red, averaging 62 days old; red with some green, averaging 64 days old; and all red, averaging 68 days old; harvested according to color. Two set of samples were obtained for each stage with the exception of the 58-day-old fruits for which there was only one sample. The 15-, 33-, 47-, and 58-day-old

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[1] This work was done as a partial fulfillment of the requirements for the Ph.D. degree at the University of Michigan. A portion of this work was done while the author held an F.C. and Susan Eastman Newcombe Fellowship in plant physiology.

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samples contained 10 to 14 fruits per sample. Because of the poor set of fruit and the injury caused by hot weather, the samples of the 62-, 64-, and 68-day-old fruits contained only four to six fruits each.

The fruits were separated into pericarp, placentae, and seeds, when present. The pericarp was cut up into pieces about ¼ inch square and each sample thoroughly mixed. Samples for dry weight determinations and juice analyses were taken from these larger samples. The dry weight was determined by drying 100 grams fresh material to constant weight in a vacuum oven at 60 degrees C. The dried samples were saved for carbohydrate and nitrogen determinations. The samples of placentae were divided into two parts, one for dry weight and the other for juice analyses.

The titratable acid of the juice was determined by using .05N NaOH with phenophthalein as an indicator. The pH was determined with a Beckman pH meter and the soluble solids with an Abbé refractometer. The reducing and total sugars were determined by extracting the dried samples with 80 per cent ethyl alcohol and determining the reducing power of an aliquot of this extract by the Hagedorn-Jensen method (3, 4). Nitrogen determinations were made on a semi-micro scale using selenium as a catalyst in the digestion.

RESULTS

As was observed by Gustafson (2), the parthenocarpic fruits have a somewhat different shape than the seeded ones. The stylar end in the parthenocarpic fruits was quite sunken. This made them shorter than the seeded fruits which normally are more or less round at the stylar end. The width of the two types of fruits was approximately the same.

By the time the fruits had reached the 15-day-old stage the seeded ones were definitely heavier than the parthenocarpic ones, and from this stage on they both increased in weight at such a rate that the ratio between the two remained more or less constant. The weight of the seeded fruits was one and a half to two times that of the parthenocarpic ones.

Another striking difference in the development of the fruits was in the placentae. Those of the parthenocarpic fruits consisted of three or four ridges which were not joined in the center; in the seeded fruits they consisted of thick ridges connected to a large central axis. In the fully developed fruits the placentae of the parthenocarpic fruits made up about 3 per cent of the whole fruit, while those of the seeded fruits made up about 6 per cent. Approximately 1 per cent of the seeded fruits was seeds.

In contrast to the tomatoes (5), peppers show very little difference between the parthenocarpic and seeded fruits in the acid content or pH. There is normally less acid in pepper fruits than in tomato fruits. The acidity, as measured by the amount of NaOH neutralized, increased in both types of pepper fruits as they ripened. There was slightly more acid in the placentae than in the pericarp of the same fruit, but there was no significant difference in acidity between the parthenocarpic and seeded fruits. The pH decreased somewhat with the increase in acidity.

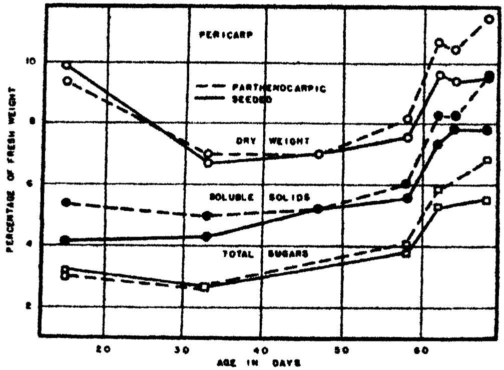

Fig. 1. Changes in dry weight, soluble solids, and total sugars of the pericarp of parthenocarpic and seeded pepper fruits.

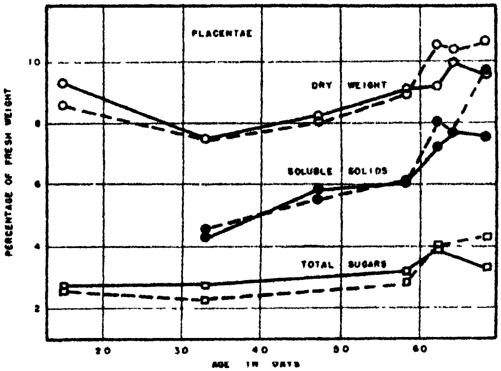

Fig. 2. Changes in the dry weight, soluble solids and total sugars of the placentae of the parthenocarpic and seeded pepper fruits.

but here again there was no difference between the seeded and parthenocarpic fruits.

Figs. 1 and 2 show the changes in percentage of dry weight, soluble solids and total sugars which took place in the pericarp and placentae of the pepper fruits as they developed. The curves show that the dry weight as percentage of the fresh weight was nearly equal in both types of fruits until they began to ripen. During the ripening process the dry weight as percentage of fresh weight increased in both types of fruits but at a more rapid rate in the parthenocarpic ones. The dry weight of the pericarp of the red ripe parthenocarpic fruits was approximately 2 per cent higher than the dry weight of the seeded fruits. The dry weight of the placentae of the red ripe parthenocarpic fruit was approximately 1 per cent higher than the dry weight of the placentae of the seeded fruits.

During the spring of 1940 a few peppers were grown in the greenhouse. The dry weight of 17 parthenocarpic and 12 seeded fruits was determined. The fruits varied in color from mostly green to red ripe. The average percentage of dry weight for the parthenocarpic fruits was 9.8 and for the seeded fruits it was 9.1. These data would indicate that the environment did not have much effect on the relation of the percentage of dry weight between the two types of fruits.

The pericarp of the 15- and 30-day-old parthenocarpic fruits had a higher percentage of soluble solids than the seeded ones. From this stage on the curves for soluble solids resembled those for dry weight. The soluble solids in the pericarp of the red ripe parthenocarpic fruits was nearly 2 per cent higher than that of the red ripe seeded fruits. The fruits of the red ripe stage were the only ones in which the placentae of the parthenocarpic fruits had a significantly higher percentage of soluble solids.

The changes in sugar expressed as percentage of fresh weight paralleled very closely the changes in percentage dry weight in both the pericarp and placentate. There was from 1 to 1.5 per cent more sugar in the red ripe parthenocarpic fruits than the red ripe seeded fruits.

If the carbohydrates are calculated on a dry weight basis an entirely different picture is obtained. On this basis all of the constituents which were analyzed, with the exception of nitrogen, showed no differences between the two types of fruits, regardless of the stage at which they were studied. This fact would indicate that the main difference between the parthenocarpic and seeded pepper fruits was one of hydration and not an actual change in the relative proportion of the different constituents.

Total nitrogen is the only constituent other than moisture in which a consistent difference between the parthenocarpic and seeded fruits was found. When expressed as percentage of dry weight the total nitrogen was higher in the pericarp of the parthenocarpic fruits than in the seeded ones at all stages except the 15-day-old fruits (Fig. 3). Eight samples varying in age from 30 to 68 days were analyzed. There was an average of 0.25 per cent more total nitrogen in the parthenocarpic fruits. The standard error of this difference was ± 0.034, indicating a high degree of significance.

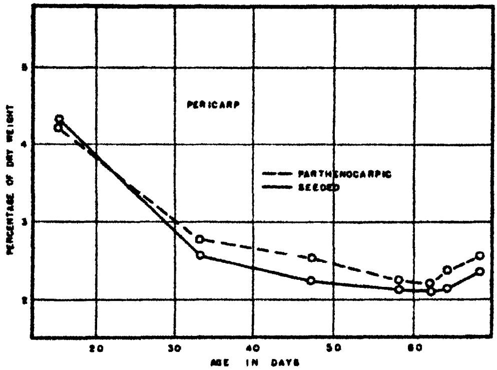

Fig. 3. Changes in the nitrogen content of the pericarp of the parthenocarpic and seeded pepper fruits.

The percentage of alcohol soluble nitrogen was slightly different at the 30- and 58-day-old stages but was the same at the other stages studied.

Discussion

It has been suggested (5) that there might be either (a) a difference in nutrient utilization due to seed formation, or (b) a difference in kind and concentration of enzymes or growth regulating substances due to the presence or absence of seeds as possible explanations of the differences between parthenocarpic and seeded tomato fruits. The high carbohydrate content of the parthenocarpic tomato fruits seemed to offer some support to the theory of difference in nutrient utilization. The same amount of organic nutrients might have entered both the parthenocarpic and seeded fruits but due to the greater metabolic activity required for development of seeds, the seeded fruits utilized more organic nutrients and thus had a lower concentration. However, the difference in acid content and size of the fruits could not be explained in this way. These later differences are controlled to a large extent by enzymes or other regulating substances. If there is a difference in the enzyme or hormone content, it must be due directly to the presence or absence of seeds. Since the fruits for all practical purposes may be considered to have developed from identical ovaries, any difference in the concentration of these regulatory substances must have originated in the seeds. The data reported in this paper on the differences between parthenocarpic and seeded peppers also seems to indicate that the seeds are a source of enzymes which control the metabolism of the fruit. There was no difference in the proportion of different carbohydrates in the two types of pepper fruits, but merely a difference in concentration. The differences in size and shape of the two fruits also indicate the presence of some growth regulatory substance in the fruit which probably originated in the seeds.

While most of the evidence seems to indicate that the differences are due to differences in regulatory substances, it is also probable that the difference in the utilization of nutrients by the seeds is also a factor in determining the chemical composition of the two types of fruits.

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The Ascorbic Acid (Vitamin C) Content of Rhubarb[1]

By E. NEIGE TODHUNTER, *Agricultural Experiment Station, Pullman, Wash.*

ALTHOUGH rhubarb is widely used, comparatively few quantitative data have been reported with regard to the vitamin C content. Hessler and Williams (8) reported that rhubarb canned by the open kettle method and stored 4½ months gave complete protection to guinea pigs in 12 gram amounts and appeared to lose no antiscorbutic value after 15 minutes heating. Birch, Harris, and Ray (3) for an unspecified variety reported 5.9 milligrams per 100 grams and Bessey and King (2) give a value of 2.1 milligrams per 100 grams by the titration method. Guerrant, Rasmussen, and Dutcher (7) reported that rhubarb juice had a vitamin C content of 27.8 milligrams per 100 milliliter but there were no details of variety or method of preparation, or concentration of the juice.

Clague, Fellers, and Stepat (5) found that fresh cooked rhubarb contained 3.2 milligrams per 100 grams and two samples of canned rhubarb had 1.5 and 1.7 milligrams per 100 grams. These values were obtained by titration and were stated to be in good agreement with values obtained by bioassay. The variety was not stated and no description of the cooking method was given.

Fixsen and Roscoe (6) in their tabulation of values for rhubarb from various sources give a range of 5.9 to 36.7 milligram per 100 grams.

Brown and co-workers (4) in a study of the effect of cooking on rhubarb reported ascorbic acid values of 6 to 7 milligrams per 100 grams of raw material for Victoria, Ruby and McDonald varieties and 11 milligrams for the Linnaeus variety.

This present study was undertaken to gain further information regarding the vitamin C content of rhubarb grown under different conditions.

EXPERIMENTAL METHODS

The varieties of rhubarb that were tested were Wine and Victoria grown in the hothouse and in the field. The rhubarb, obtained from Summer Rhubarb Growers Association, was received at the stage of prime maturity for harvesting, and for each variety 15 pound lots were received at two different times. Analyses were repeated on the same varieties the following year.

For each analysis, of the raw rhubarb, 10 stalks were used and a ¼ inch section from the center of each stalk was taken to make a composite sample; from 6 to 12 samples were analysed for each variety. The method used was that of Bessey (1) for the Evelyn photoelectric colorimeter and triplicate readings were made with aliquots from each extraction; with this photoelectric method the pink color of the rhubarb extract does not interfere with the determination.

Analyses were also made on cooked samples of rhubarb using the whole stalk. Approximately 450 grams of rhubarb were weighed, cut into sections and placed in a pyrex dish, and a syrup of 1 cup of sugar and ¼ cup of water was poured over the rhubarb, which was then cooked in an oven at 350 ±1 degree F (Bristol automatic oven control) for 30 minutes. When cooked, the sample was thoroughly mixed and portions were removed into weighed bottles containing 3 per cent metaphosphoric acid. The weighed samples were then analysed for vitamin C in a similar manner to the raw rhubarb. Analyses were also made of ¼ inch cross sections from the leaf and from the stem end of the same stalks.

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[1] Published as Scientific Paper No. 496, College of Agriculture and Agricultural Experiment Station, State College of Washington.

RESULTS AND DISCUSSION

Comparison of Wine and Victoria Varieties Grown in the Hothouse:—The data are summarized in Table I. The two varieties of hothouse grown rhubarb differ in vitamin C content, the Wine variety being the richer of the two.

TABLE I—ASCORBIC ACID CONTENT OF RHUBARB OF TWO VARIETIES, GROWN IN FIELD AND HOTHOUSE

Description		No. of Samples	Average Ascorbic Acid Content (Mg Per 100 Gm)
	Victoria		
Hothouse	Apr 9, 1940	12	3.5
Hothouse	Feb 7, 1941	8	5.8
Hothouse	Feb 14, 1941	5	3.3
Field	May 7, 1940	6	6.8
Field	Apr 23 to 29, 1941	8	8.0
	Wine		
Hothouse	Apr 15, 1940	12	6.7
Hothouse	Feb 19 to 28, 1941	12	5.8
Field	May 1, 1940	8	6.5
Field	Apr 29, 1941	8	16.7
Field	May 6, 1941	8	12.0

The samples of Victoria variety analysed in 1940 were received at the end of the season; this may account for the low value of 3.5 milligrams ascorbic acid per 100 grams rhubarb obtained. In the following year the first samples consisted of long slender stalks and a value of 5.8 milligrams per 100 grams was found; however, the sample received the following week gave the same lower value obtained the previous year. As the season progresses and the rhubarb increased in maturity, it appears to decrease in ascorbic acid content.

The samples of hothouse rhubarb of the Wine variety for both years were found to be in good agreement; 6.7 milligrams per 100 grams in 1940, and 5.8 milligrams the succeeding year.

Comparison of Field and Hot-House-Grown Rhubarb:—The field rhubarb of the Victoria variety was higher in ascorbic acid content in both years than that grown in the hothouse (Table I). With the Wine variety for the first year, the values were the same for the hothouse and the field product but the following year higher values of 16.7 and 12.0 milligrams per 100 grams were obtained. There is no explanation for this difference; however, it is possible that rhubarb grown in different soils or with different fertilizer treatments might vary widely in ascorbic acid content, and in this study there was no control of the growing conditions of the samples used.

Effect of Cooking on the Vitamin C Content:—No appreciable loss of ascorbic acid was found after cooking. Twelve samples of Wine variety, hothouse grown, were found to have an average value of 5.0 milligrams per 100 grams of rhubarb; with allowance made for the addition of water and sugar, and calculated to the weight of raw rhubarb used in each sample this is 6.3 milligrams per 100 grams. A similar number of samples of the raw rhubarb showed an average value of 6.7 milligrams per 100 grams; the loss in cooking may, therefore, be considered negligible. For the field-grown rhubarb, eight samples had an average value of 4.3 milligrams per 100 grams; calculated to the fresh weight basis this was 5.6 milligrams as compared with 6.5 milligrams per 100 grams of uncooked product.

For the Victoria variety, hothouse grown, the average value was 2.4 milligrams per 100 grams cooked material, or 3.2 milligrams calculated to the raw weight, whereas the similar samples of uncooked rhubarb had a value of 3.5 milligrams per 100 grams. For the field-grown product the values were 4.5 milligrams per 100 grams cooked material, or 5.6 milligrams on the raw weight basis and 6.8 milligrams for the uncooked rhubarb. Ascorbic acid is resistant to destruction when in acid solution and the negligible loss of ascorbic acid when rhubarb was cooked is probably due to the pH of the rhubarb. Measurements with the Beckman pH meter showed rhubarb to have similar pH values for both varieties ranging from 2.85 to 3.29.

Dehydroascorbic Acid:—The method of determination of dehydroascorbic acid is unsatisfactory because of the difficulty of removing the last traces of hydrogen sulphid used to reduce any of the oxidized form of ascorbic acid that might be present. However, when this method was used, values of 4.0 and 3.5 milligrams were obtained on samples which, by the routine analyses, were found to contain 3.5 milligrams per 100 grams. The ascorbic acid present in rhubarb is, therefore, believed to be all in the reduced form.

Comparison of Stem End and Leaf End of the Stalk:—For the same samples of Victoria field-grown rhubarb where the average value for sections from the center of the stalk was 6.1 milligrams, sections from the stem end had a value of 6.9 milligrams and from the leaf end of the stalk 9.6 milligrams per 100 grams. For the Victoria variety grown in the hothouse, values were 3.4 milligrams for the center section, 4.2 milligrams for the stem end and 5.9 milligrams per 100 grams of leaf end of the stalk. The Wine variety, hothouse grown, had the following values: 5.4 milligrams, center section; 3.9 milligrams, stem end; and 7.9 milligrams, leaf end.

For the Wine variety grown in the field, a similar range of values was found; center sections contained 10.7 milligrams per 100 grams; 9.7 milligrams for the stem end and 15.5 grams per 100 grams for the leaf end.

There is thus seen to be a greater concentration of ascorbic acid in that part of the rhubarb stalk which is close to the leaf.

SUMMARY

The ascorbic acid content of fresh rhubarb grown in the hothouse ranged from 3.5 to 5.8 milligrams per 100 grams for the Victoria variety and from 5.8 to 6.7 milligrams for the Wine variety. The field-grown product contained from 6.8 to 8.0 milligrams for the Victoria variety and 6.5 to 16.7 milligrams per 100 grams for the Wine variety. The leaf end of the rhubarb stalk was higher in ascorbic acid than the stem end. There was practically no destruction of ascorbic acid when rhubarb was cooked in a covered dish in the oven.

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Yield and Quality Tests of Edible Soybeans Grown for Canning in Maryland[1]

By E. P. WALLS, *University of Maryland, College Park, Md.*

FIELD and canning trials with edible soybeans were made a part of the 1940 and 1941 programs in canning crops research at the University of Maryland Agricultural Experiment Station. Each of nine varieties grown in 1940 and ten varieties grown in 1941 were compared for yields and samples of each canned for comparison of quality of the canned product. Each variety was sown in quadruplicated plots, with rows 3 feet apart and plants 4 inches apart in the row. Planting dates were May 29 in 1940 and May 26 in 1941. A 5–10–5 fertilizer was applied in bands on each side of the row at the rate of 650 pounds per acre. Seed for these trials was furnished by the Associated Seed Growers, Incorporated.

The method of harvesting consisted of pulling entire plants, stripping off the pods by hand and shelling these in a pea huller. The stage of maturity at harvest time was as nearly the same for each variety as careful field inspection could make it.

The data secured from field trials are presented in Table I.

TABLE I—YIELDS OF UNSHELLED PODS, SHELLED BEANS, PERCENTAGE OF BEANS TO PODS BY WEIGHT AND DAYS FROM PLANTING TO HARVEST OF TEN VARIETIES OF EDIBLE SOYBEANS

Variety	Yield (Pounds Per Acre)				Per Cent of Beans to Pods by Weight		Days From Planting to Harvest	
	1940		1941					
	Unshelled Pods	Shelled Beans	Unshelled Pods	Shelled Beans	1940	1941	1940	1941
Sousei	——*	——	5387	3100	——	58	——	99
Giant Green	2124	890	4504	2882	42	64	99	100
Bansei	2496	1234	9763	5474	49	56	105	100
Toku	3616	1847	9223	5068	51	55	106	101
Jogun	3323	1389	8494	4477	42	53	111	105
Higan	5191	2668	7610	3585	51	47	112	115
Hokkaido	4370	1798	8725	4885	41	56	113	112
Emperor	5214	2119	6778	3565	41	53	114	115
Willomi	4842	1992	10520	5451	41	52	118	108
Imperial	4869	2264	8384	4279	47	51	119	112
Differences necessary for significance. Odds, 19 to 1.	829	388	716.9	397.6				

*Not grown in 1940.

Examination of yields of shelled beans in Table I shows for 1940 that Higan outyielded all other varieties and that Imperial, the second highest yielder did not significantly differ from Emperor and from Willomi, but was significantly higher than any of the other varieties except Higan.

For 1941, Bansei and Willomi, which yielded approximately the same, produced more shelled beans than any of the other varieties. Toku and Hokkaido, which might be considered in the second high yielding group, are higher than any of the other varieties except Bansei and Willomi.

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[1] Scientific Paper No. A 23, Contribution No. 1833 of the Maryland Agricultural Experiment Station.

The higher yields of 1941 may be accounted for by the fact that the land on which the crop was grown was of a higher fertility level than that used the previous year and the season also appeared to be more favorable.

Since no well-recognized canning procedure was available, the one used was furnished by the Research Department of the American Can Company. After being hulled, the beans were given a thorough wash, at first with cold water and then with hot water at about 190 degrees F. Following this the beans were hand-picked to remove any extraneous material and broken or over-mature beans. The beans were then blanched for 10 minutes at 190 degrees F. On removal from the blanch they were washed with lukewarm water and immediately filled into plain No. 1 Picnic cans, 211 by 400. No attempt was made to maintain a uniform fill-in weight. Salt brine containing 25 pounds of salt per 100 gallons of water which had been thoroughly boiled to expel air, was then added at a temperature near the boiling point, after which the cans were immediately closed and processed at 240 degrees F for 40 minutes and promptly cooled.

After the beans had been canned a sufficient length of time for them to "set up" in the can, from 3 to 3½ months, a group of judges, including food technologists, licensed Federal graders, canners and others working in the industry, met and very critically examined canned samples of each variety. These were scored for *color, character of liquor, flavor* and *maturity*. In the scoring system used under each of these items, 1 = excellent; 2 = good; 3 = fair; and 4 = poor.

After each of the judges had scored the various samples, their scores were averaged, for each of the several items considered, as shown in Table II. It should be borne in mind that the higher the quality, the lower is the numerical score. In the evaluation of quality items considered, each of the four has been given equal value for the purpose of this comparison.

TABLE II—AVERAGE SCORES OF SIXTEEN JUDGES FOR COLOR, CHARACTER OF LIQUOR, FLAVOR AND MATURITY OF NINE SAMPLES OF EDIBLE SOYBEANS CANNED IN 1940

Variety	Color	Character of Liquor	Flavor	Maturity	Average Score For All Quality Items
Giant Green	2.10	1.62	2.23	2.13	2.02
Bansei	1.83	1.50	2.08	2.02	1.85
Toku	2.11	1.51	2.81	2.57	2.25
Jogun	2.31	1.94	3.00	2.35	2.40
Higan	1.92	2.06	1.98	2.00	1.99
Hokkaido	2.13	2.40	2.29	2.29	2.28
Emperor	1.27	1.77	1.63	1.52	1.55
Willomi	2.94	2.92	2.71	2.48	2.76
Imperial	2.11	3.02	2.48	2.04	2.41
Differences necessary for significance Odds: 19 to 1	.36	.36	.36	.36	.27

This shows that Emperor was significantly higher in quality than any of the others. Bansei, Higan and Giant Green fall into a second group and are not significantly different from one another. A third group is composed of Toku, Jogun, Imperial and Hokkaido, which are not significantly different from one another. Willomi is significantly lower than any of the other varieties.

It is interesting to note that although the average score for all items for Emperor indicates significantly higher quality than for any other variety, three others received higher quality ratings for the character of the liquor, *i. e.*, Bansei, Toku and Giant Green. In all other quality items considered, however, Emperor ranked first by a good margin.

According to the aveage score of the 16 judges the poorest color was exhibited by the canned sample of the variety Willomi; the poorest character of liquor by Imperial; the poorest flavor by Jogun and the poorest maturity rating by Toku and Willomi.

The samples canned in 1941 were judged for the same quality items as in the previous year and the average scores in Table III are the result of this examination.

TABLE III—AVERAGE SCORES OF THIRTEEN JUDGES FOR COLOR, CHARACTER OF LIQUOR, FLAVOR AND MATURITY OF TEN SAMPLES OF EDIBLE SOYBEANS CANNED IN 1941

Variety	Color	Character of Liquor	Flavor	Maturity	Average Score For All Quality Items
Sousei	1.923	3.692	1.923	2.077	2.404
Giant Green	2.000	2.231	2.692	2.385	2.327
Bansei	2.615	2.462	2.462	2.231	2.443
Toku	1.769	1.462	3.000	2.462	2.173
Jogun	1.923	2.462	1.923	1.692	2.000
Higan	1.923	2.538	2.462	2.077	2.250
Hokkaido	2.077	2.154	2.462	2.308	2.250
Emperor	1.769	1.385	2.000	1.846	1.750
Willomi	1.923	1.615	2.077	2.000	1.904
Imperial	2.077	2.538	2.615	2.308	2.385
Differences necessary for significance Odds: 19 to 1.	0.396	0.541	0.555	0.503	0.588

The variety Emperor again scored highest in quality in 1941 and is significantly higher than Imperial, Sousei and Bansei but not significantly higher than the six other varieties.

While Emperor ranked highest in the average score for all items it was equaled in the score for color by Toku; exceeded all other varieties in character of liquor, (which is a very important item in evaluating the quality of canned samples of this product) ; was slightly exceeded in flavor by Jogun and Sousei; and was second in maturity rating, in which item Jogun received the best score.

According to the average scores of the 13 judges the poorest color was exhibited by Bansei; the poorest character of liquor by Sousei; the poorest flavor by Toku and the poorest maturity rating by Toku.

The variety Emperor, while scoring highest in each of the two years for canning quality, was not significantly higher in quality in the 1941 samples than Giant Green, Toku, Jogun, Higan, Hokkaido or Willomi. It was significantly higher in quality than any of the other varieties in 1940. From the standpoint of canning quality alone Emperor attained the highest rank in two years considered, but when considered from the standpoint of commercial production this quality score is so nearly approached by some of the other varieties, that when yield is considered along with quality, some of the other varieties might be more desirable.

Comparative Yield and Composition of the Seedling L 4–5 and Triumph Sweet Potatoes

By W. D. KIMBROUGH, *Louisiana Agricultural Experiment Station, Baton Rouge, La.*

ABSTRACT

This material will be published in full as part of an experiment station bulletin from the Louisiana Agricultural Experiment Station.

TWO years' results of a time of planting and time of digging experiment are reported. The results show the L 4–5 consistently outyielded the Triumph variety and also had a higher starch content. For these reasons the L 4–5 seems superior to the Triumph as a starch and feed variety and will likely replace it.

Studies of Gray-Wall of Tomato

By O. A. LORENZ and J. E. KNOTT, *University of California, Davis, Calif.*

"GRAY-WALL" is a serious problem in the production of mature-green tomatoes in California. The fruits affected have on the surface a grayish cast related to a dark chlorophyll layer in the parenchymatous cells of the wall tissues. The chlorophyll does not always accumulate uniformly over all the exposed areas, but may give the fruit a more or less mottled appearance. The term "gray-wall", although used quite freely by the trade, is not fully descriptive. Since the affected fruits often show a relatively thin wall or pericarp on the side most exposed to the sun, perhaps the term "thin-wall" would be more appropriate. The wall may be less than one-third as thick on the exposed side as on the unexposed side. Such a condition is illustrated in the sections shown in Fig. 1. Fruits developing in the open and exposed to the sun and air on all sides have, in general, much thinner walls than fruits shaded by the vines.

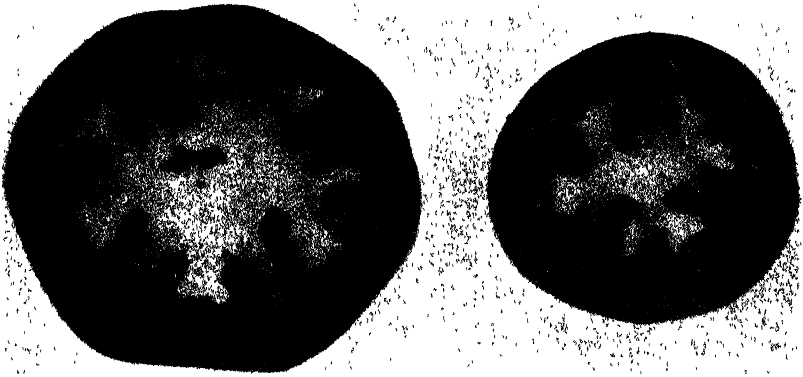

FIG. 1. Gray-wall and thin-wall on the exposed portions of mature-green tomato fruits. (Note the chlorophyll accumulation in the thin-wall region of the pericarp.)

Frequently radial bands of dark green tissues approximately at the center of the periphery of the locule are found on the half of the fruit near the stylar scar when that portion is exposed to the sun. These bands may or may not accompany the thin-wall condition, and are to some extent a varietal characteristic.

Some sheds packing mature-green tomatoes have been known to discard over 20 per cent of the fruits because of gray-wall. This culling is in addition to the discarding of many fruits in the field before the fruits are brought to the packing sheds. The thin-wall condition often accompanying gray-wall may cause soft locules and thus result in rejection of the fruit by inspectors. It is claimed by the trade that thin-wall fruits often are subject to greater injury in transit or storage, especially when the thin section rests against other fruits.

The authors have observed or learned of gray-wall on tomatoes grown in all important tomato-growing sections of California, although the trouble is probably most severe in the interior valleys. Publications from Florida (6) and Texas (7) give photographs of cross-sections of puffy tomatoes. Although these bulletins do not mention the thin-wall condition, some of the cross-sections show a narrow wall and chlorophyll accumulation on one side of the fruit.

In this paper the terms "gray-wall" and "thin-wall" are used interchangeably except where one or the other was used as a specific basis for classifying fruits.

GREENHOUSE AND FIELD OBSERVATIONS

As field observations in 1940 and 1941 revealed, gray-wall occurred only on tomatoes exposed to the sun and was most severe on the portion of the fruit exposed to the sun on the south. It occurred more frequently on those fruits developing on the south side of the vine than on those developing on the north side, especially during the fall months. Gray-wall was more prevalent on fruit on vines that became defoliated than on fruits developing on vines that provided adequate shade. Though found on all varieties observed, it was most severe on Pearson and other varieties that normally provided inadequate shade for the fruit. For example, in counts of several hundred partially exposed fruits of each variety made on August 26, 1941, Pearson had thin-wall on 48 per cent of such fruits, Riverside 29 per cent, Norton and Pritchard each 25 per cent and, 133–6 only 18 per cent.

Gray-wall occurred on the exposed side of a few mature-green fruits of Pearson on pruned and trained plants in the greenhouse at Davis in February, 1941, and was observed on fruits of Sutton's Best of All in a greenhouse at San Pablo near San Francisco in April, 1941. In a later planting of Pearson and 133–6 in the greenhouse at Davis, thin-wall was produced early in March on all fruits whose exposed side was coated with carbon black mixed with lanolin. At the same time, untreated exposed fruits or fruits enclosed in cloth, kraft, or colored cellophane bags failed to develop thin-wall. In late April and May, untreated exposed fruits showed thin-wall.

RIPENING STUDIES

Experiments were conducted to determine the relation between gray-wall, thin-wall, and subsequent ripening. In one series of experiments, samples of about 200 exposed green fruits showing the external gray-wall were divided in two lots. Half the fruits were cut at harvest to find the percentage of thin-wall, and the remainder were cut after ripening in storage. The data from two such experiments (Table I) show that storage does not change the percentage of fruits showing thin-wall. In one lot, for example, 58 per cent of the fruits showed thin-wall at time of harvest, whereas the ripe fruits of a comparable lot cut after storage showed 52 per cent thin-wall. In the second experiment comparable figures were 55 and 46 per cent. In many cases even though the walls were of uniform thickness the external

TABLE I—Effect of Exposure to the Sun on the Presence of Thin-wall Before and After Storage and on the Subsequent Ripening of Tomato Fruits (Each Sample Included Approximately 200 Fruits, All of Which Showed External Symptoms of Gray-wall)

Date of Harvest (1941)	Per Cent Fruits Having Thin-Wall When Cut After Harvest	Wall Condition of Fruits Cut After Storage*			
		Fruits Having Thin-Wall On One Side		Fruits of Uniform Wall Thickness	
		Per Cent Having White or Yellow Areas in Wall	Per Cent With Normal-Wall Color	Per Cent Having White or Yellow Areas in Wall	Per Cent With Normal-Wall Color
Aug 26	58	48	4	40	8
Sep 9	55	45	1	25	28

*Records taken approximately 3 weeks after fruit stored in the dark at 65 degrees F; at this time practically all fruits showed dark red color.

gray-wall appearance of the green fruit was later associated with a white or yellowish area in the wall of the ripe fruit.

In a second series of experiments two lots of approximately 200 fruits each were harvested on September 22, 1941. These were mature-green tomatoes which, during their development, had been fully exposed to the sun on the southwest so that external gray-wall resulted on that side of the fruit. The external gray-wall area on each was marked with ink, and this area was used to determine whether or not thin-wall was present, as compared to the wall thickness on the opposite side of the fruit. Half the fruits of each lot were cut at harvest, and the remainder on October 10 after ripening in storage. The tomatoes of one showed 41 per cent thin-wall in the gray-wall section of the fruit cut before storage and 34 per cent in those cut after ripening. For the other lot, comparable figures were 34 per cent before storage and 48 per cent after ripening. This fact illustrates further that the thin-wall condition persists through ripening. Thin-wall, where found, was always associated with some of the external gray-wall condition; but thin-wall does not always accompany gray-wall, as was also indicted by the data in Table I. Although, in three out of four comparisons, there was a somewhat smaller percentage of thin-wall fruits in the lots cut after ripening than in comparable lots cut before storage, the differences are attributed to sampling errors.

In another experiment, mature-green exposed fruits of the 133–6 variety were harvested on September 23, 1941. In the field these were seemingly free of sun injury. By close examination after harvest they were divided into two lots; those free of any indication of a yellow discoloration on the surface associated with external gray-wall; and those showing a very slight yellowing, usually at the shoulder of the fruit. It is assumed that gray-wall is a mild form of sun injury, and a definite separation of the two was not possible. The fruits classified as showing sun injury had slight yellowish areas on the surface where they had been exposed to the sun. When fully ripe on October 10, the fruits were cut and classified according to uniformity of wall thickness and color. Disease was not a factor during ripening. As the data in

TABLE II—EFFECT OF GRAY-WALL AND SUN DISCOLORATION ON THE SUBSEQUENT RIPENING OF TOMATO FRUITS (MATURE-GREEN FRUITS PICKED AND STORED AT 65 DEGREES F ON SEPTEMBER 23, 1941; EXAMINED WHEN FULLY RIPE ON OCTOBER 10, 1941)

External Description of Mature-Green Fruit	Classification Based on External Appearance of Ripe Fruit					
	Fruits Ripening Unevenly or Showing Discolored or Yellow Areas			Fruits Ripening Normally		
	Classification Based on Internal Appearance			Classification Based on Internal Appearance		
	Number of Fruits With Walls of Uniform Thickness and Normal Color	Number of Fruits Having Thin-Wall But Normal Color in the Wall	Number of Fruits Having Thin-Wall and White or Yellow Discoloration in Wall	Number of Fruits With Walls of Uniform Thickness and Normal Color	Number of Fruits Having Thin-Wall But Normal Color in the Wall	Number of Fruits Having Thin-Wall and White or Yellow Discoloration in Wall
Fruits showing gray-wall but free of any discoloration on the surface.....	11	2	30	20	6	11
Fruits showing gray-wall and also discoloration on the surface indicative of sun injury	16	10	30	11	5	11

Table II reveal, it was not possible to determine from the external appearance at harvest whether or not the fruits would ripen with a uniform red wall color; nor was it possible to tell externally in the fruits apparently ripening normally whether the walls were of uniform thickness and normal color. For example, of the 80 fruits supposedly free of sun injury at harvest, 43 ripened unevenly as judged by external ripe appearance, and of those only 11 were found to have walls of uniform thickness and normal color. Of the 37 fruits in this lot which ripened normally, as judged by external ripe appearance, only 20 had walls of uniform thickness and normal color. The remainder of the data show that even if the fruits show some yellowing on the shoulder at harvest time, some will ripen with good external color and with walls of uniform thickness and normal color.

MICROSCOPIC STUDIES

Microscopic examination was made of the pericarp tissues of thin-wall fruits. Sections of normal and thin-wall tissues of the same fruit were killed in formalin-acetic acid-alcohol mixture, imbedded in paraffin, sectioned, and stained with fast green in the usual manner. The pericarp of the tomato fruit consists of a layer of epidermal cells, just beneath which lie three or four layers of collenchymatous tissue. Beneath these are about 25 layers of large thin-walled parenchyma cells. The difference in wall thickness between the thin-wall and normal-wall sections of the same fruit was due entirely to the smaller size of the cells in the thin-wall sections. This situation is illustrated in Fig. 2.

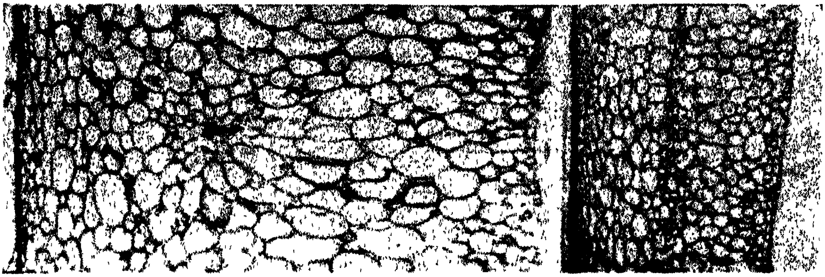

FIG. 2. Normal (left) and severe thin-wall (right) tissue from opposite sides of a gray-wall tomato fruit. (Note the smaller and seemingly compressed parenchymatous cells in the thin-wall section, and also the pronounced accumulation of chlorophyll in the parenchyma cells near the center of this section; equal magnification.)

In eight comparisons the average number of parenchyma cells in the thin-wall region of the pericarp was 24, as compared with 23 in the region where the pericarp of the same fruits was of normal thickness. Likewise there was no difference in the number of collenchyma cells between the thin-wall and normal-wall tissues. The parenchyma cells just under the layers of collenchyma were often highly compressed tangentially and showed the least enlargement. Obviously, the thin-wall condition is due to smaller cell size rather than to a decreased number of cells.

PHYSIOLOGICAL STUDIES

Bags of red or blue cellophane, glassine, kraft paper, and cloth were used to enclose the fruits that had reached a diameter of ½ to ¾ inch. In other cases aluminum paint or carbon black mixed with lanolin were applied to entire fruits or to certain portions. The fruits were fully exposed to the sun or were shaded on either the northeast or southwest sides by stakes or foliage. Two series, started on August 8 and September 12, have been combined in Table III. In addition, those same treatments were applied to fruits deep in the vines and completely shaded. Since none of the latter developed thin-wall, the data for them are not tabulated.

The findings show that the side of the fruit shaded from the sun's rays does not develop thin-wall, and at that time of the year if the fruit is fully exposed to the sun the southwest side is most liable to develop thin-wall. When, however, the southwest side was shaded, some fruits had a thinner wall on the northeast or east side. No fruits enclosed in kraft bags developed gray-wall or thin-wall. In cloth bags only those fruits touching the very top of the bag, where they received the sun's rays, developed thin-wall. Glassine bags did not reduce the amount of thin-wall. In the cellophane bags those fruits that showed thin-wall were the ones whose development caused the cellophane to be stretched tightly against their surface on the exposed side. Aluminum paint or carbon black greatly accentuated the amount of thin-wall. When the sunlight was subdued by the use of colored cellophane bags, or by covering the fruits with carbon black, the fruits did not show

TABLE III—EFFECT OF DIFFERENT FRUIT TREATMENTS ON THE NUMBER OF FRUITS SHOWING THIN-WALL

Treatments	Number of Fruits Showing Thin-Wall on		Number of Fruits Free of Thin-Wall
	Northeast Side of Fruit	Southwest Side of Fruit	
	Fruits Fully Exposed to the Sun		
Check, no treatment	0	21	4
Carbon black, entirely about fruit	0	12	1
Carbon black, on northeast side of fruit	9	1	7
Carbon black, on southwest side of fruit	0	24	0
Aluminum paint, entirely about fruit	0	6	0
Aluminum paint, on northeast side of fruit	7	0	1
Aluminum paint, on southwest side of fruit	0	9	0
Cellophane bag, fully enclosing fruit	0	22	35
Kraft paper bag, fully enclosing fruit	0	0	22
Cloth bag, fully enclosing fruit	0	9	143
Glassine bag, fully enclosing fruit	0	16	4
	Fruits Shaded on the Northeast Side		
Check, no treatment	[illegible]	[illegible]	[illegible]
Carbon, entirely about fruit	0	20	0
Carbon, on northeast side of fruit	0	0	3
Carbon, on southwest side of fruit	0	3	0
Aluminum paint, entirely about fruit	0	10	2
Aluminum paint, on southwest side of fruit	0	12	0
Cellophane bag, fully enclosing fruit	0	11	2
Glassine bag, fully enclosing fruit	0	7	1
	Fruits Shaded on Southwest Side		
Check, no treatment	4	0	18
Carbon, entirely about fruit	2	0	8
Aluminum paint, entirely about fruit	6	0	8
Aluminum paint, on norheast side of fruit	11	0	0
Cellophane bag, fully enclosing fruit	1	0	10
Glassine bag, fully enclosing fruit	0	0	10

gray-wall. Fruits which were completely covered by carbon black were without any green color.

Temperature determinations were made of the wall tissues of tomato fruits. Thermocouples were inserted tangentially about 1 centimeter into the wall of the fruit so that the junctions of 24-gauge wire were about 2 millimeters below the surface. Readings were made every 2 hours during the day, and Tables IV and V give data for 2 of the 6 days on which temperature records were taken. September 13 was normal, whereas September 16 was a bright day with little air movement. The exposed side of the fruit was much hotter than the under side or than the air from 9 a.m. until after 3 p.m. Differences of as much as 15 to 20 degrees F between the two sides during the middle of the day were not uncommon. The tops of fruits showed a range in daily temperature of 50 to 60 degrees F or more. Fruits covered with aluminum paint or carbon black were hotter than untreated fruits. As Table V shows, the exposed portion of a fruit covered with carbon black attained a temperature as high as 138 degrees F. This fruit developed sunscald during this one day of exposure. Comparison showed that the east side of a fruit did not get so warm as the top, and west portions. A completely shaded fruit was cooler than the air temperature during the hot part of the day. Harvey (3) found that the wall tissue on the south side of tomato fruits grown in Minnesota was as much as 10 degrees F hotter than the north side of the same fruits.

TABLE IV—TEMPERATURE OF WALLS OF TOMATO FRUITS ON SEPTEMBER 13 AND 14, 1941

Description of Tomato Fruits	Temperature (Degrees Fahrenheit)							
	September 13, 1941							September 14, 1941
	7:00 A.M.	9:00 A.M.	11:00 A.M.	1:00 P.M.	3 00 P.M.	5:00 P.M.	6:30 P.M.	1:00 P.M.
Side of fruit fully exposed to the sun	53	76	110	109	105	87	70	101
Under side of the fruit above	51	75	95	95	103	89	72	90
Side of fruit painted with aluminum and exposed to the sun	52	80	118	118	108	88	70	108
Under side of the fruit above	50	64	87	95	96	83	74	76
Side of fruit covered with carbon and exposed to the sun	53	84	117	115	113	94	72	112
Under side of the fruit above	49	66	90	95	99	94	75	91
Side of fruit covered tightly with blue cellophane and exposed to the sun	53	73	122	123	119	96	74	113
Side of fruit enclosed in glassine bag and exposed to the sun	51	74	113	110	111	91	75	110
Air temperature in shade	52	67	80	84	84	77	70	80

Wall temperatures as high as 127 degrees F were obtained in the field. MacGillivray (4) showed that exposed tomato fruits grown in Indiana attained temperatures as high as 118 degrees F ½ inch below the surface. Exposed fruits were often 10 degrees F hotter than shaded fruits during the hot part of the day.

Normal and thin-wall tissues of the same tomato fruits were taken

TABLE V—TEMPERATURE OF WALLS OF TOMATO FRUITS ON SEPTEMBER 16, 1941

Description of Tomato Fruits	Temperature (Degrees Fahrenheit)						
	7:00 A.M.	9:00 A.M.	11:00 A.M.	1:00 P.M.	3:00 P.M.	5:00 P.M.	6:30 P.M.
Side of fruit fully exposed to the sun	63	84	110	115	106	90	73
Under side of the fruit above	61	77	90	94	94	88	75
Side of fruit painted with aluminum and exposed to the sun	60	82	106	118	110	93	80
Under side of the fruit above	57	82	102	105	98	88	73
Side of fruit covered with carbon and exposed to the sun	59	83	124	127	114	100	78
Under side of the fruit above	57	81	95	99	97	96	79
Side of fruit enclosed in glassine bag and exposed to the sun	57	80	107	115	104	93	77
Fruit deep in vines in complete shade	53	60	67	77	80	80	77
Side of fruit fully exposed to the sun	57	88	110	120	112	97	75
East side of fruit above	58	88	102	102	96	92	75
West side of fruit above	51	69	106	105	113	98	78
Side of fruit covered with carbon and exposed to the sun	56	95	120	138	122	107	82
Air temperature in shade	54	69	78	85	87	82	68

for dry-matter determinations on August 27, September 12, and October 13, 1941. There were a total of 11 comparisons. The samples were taken about 3 o'clock in the afternoon, after which they were dried under vacuum at 70 degrees C for 12 hours. Thin-wall tissues were higher in percentage of dry weight than were normal tissues of the same fruits. The thin-wall tissue averaged 6.73 per cent dry weight as compared with 5.93 per cent for the normal tissue. The difference was significant by odds greater than 4999:1 by Student's method of analysis.

Because the difference mentioned above may have measured the effect of the thin-wall condition rather than the possible cause, mature-green tomatoes taken from inside the vines and not previously exposed to the direct sun were shifted from inside the vines late in the afternoon and exposed until 3 p.m. the following day. Samples for dry-matter determinations were then taken from the exposed and unexposed portions. There were 16 comparisons made on September 16, October 1, and 14, 1941. The average dry weight as per cent of fresh was 5.77 for the exposed portion of the fruit as compared with 5.40 for the unexposed. The difference, though small, was highly significant (odds greater than 9999:1) and indicates that exposure to the sun reduced the water content of the exposed portion.

Discussion and Summary

The external gray-wall condition of green tomatoes appears to result from the high light intensity prevailing in California, which causes the development of chlorophyll in the wall tissues. During the period when most of the tomatoes are produced in California intense sunlight persists day after day. This is in contrast to conditions in the eastern United States where there is invariably some cloudy weather although the temperature on certain days may be as high as it is in California. Accompanying the high light intensity is a heat effect. Thin-wall fruits seem to be the result of this heat effect. Exposed portions of the fruit often attain wall temperatures as high as 115 degrees F, whereas the shaded portions are 10 to 20 degrees cooler. This heating of the exposed portion evidently results in a movement of water out of the wall tissues of the exposed side. The heat from the sun probably raised the vapor pressure of the tissue on the exposed side to such an extent that a vapor-pressure gradient existed between the exposed and unexposed portions of the fruit and water was actually distilled from the exposed side to the interior or to the shaded side of the fruit. As Curtis (1, 2) has shown, exposure of tomato or apple fruits to heat on one side causes a distillation of water to cooler portions of the fruit. A 15-degree Fahrenheit difference in temperature between the exposed and shaded portions when the temperature of the exposed portion is over 100 degrees F would increase greatly the vapor-pressure difference between the two sides of the fruit. Actually the vapor pressure of pure water at 80 degrees F is 26 millimeters of mercury as compared with 49 millimeters at 100 degrees F and 87 millimeters at 120 degrees F. Although the vapor pressure of the tissues would not be the same as that of pure water, the differences in the tissue for the various temperatures would be comparable.

Probably because of a water deficit in the exposed tissues, cell enlargement fails to take place, with the result that at maturity the exposed side of the fruit has a thinner wall than the shaded. Apparently, therefore, thin-wall is a developmental abnormality, and often fruits as small as ½ inch in diameter show a thinner pericarp on the exposed side. It follows that the thin-walled condition should be related to a reduction in cell size rather than in number, since Smith (5) found that the pericarp had reached its maximum number of cells as early as 2 weeks after pollination. The fruit at this stage of growth was not over 12 millimeters in diameter. The degree of thin-wall is thus associated probably with the stage of development of the fruit when it was exposed to the sun as well as with the position on the plant in respect to the foliage. It follows that if cell enlargement is limited by the supply of water required for cell turgor, then fruits exposed to the sun during their later stages of development would not be expected to show such severe symptoms of thin-wall as fruits exposed during the early stages. Fruits that develop to their approximate size in the shade of the vines and are then exposed usually sunscald before showing any pronounced symptoms of thin-wall.

Since a yellow or discolored area occurs in the pericarp of ripe fruits which in their mature green stage showed gray-wall, but no external evidence of sun injury, the thin-walled condition may be a case of mild sunscald.

Gray-wall fruits usually ripen so that there is no serious external evidence of the previous existence of the gray-wall condition. There may, however, be some slight yellowing on the portion receiving the most heat from the sun. Internally, on the other hand, there are two reasons that might justify culling of gray-wall fruits by the shippers. First, if the thin-wall condition is pronounced, the wall may be so weak as to suffer injury or collapse in shipment and handling in the ripening rooms. Second, the yellow area sometimes present in the wall of the ripe tomato at the place where gray-wall occurred may detract from the appearance of the sliced fruit.

Since the conditions that cause gray-wall seem to be inherent with the high light intensity in California, with consequently results in heating of the fruit pericarp, the recommendations for the control of gray-wall are limited. First, varieties that have an abundance of foliage and give good shade protection to the fruit should be grown. Efforts should be made to control diseases and insects that would cause defoliation of the plants and consequent exposure of the fruit. Fertilizers, especially if nitrogenous, may increase the amount of foliage and thus reduce the amount of gray-wall.

In picking, one should not throw the vines over and thus expose the fruits. Lack of care in this matter would tend to cause sunscald of the mature fruits and gray-wall of the younger fruits.

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Factors Influencing Shoulder Bruises of Green-Wrap Tomatoes[1]

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SHOULDER bruises appear on ripened tomatoes as dark, almost black areas that are usually flattened or slightly sunken. These bruises not only detract from the appearance of the fruit but frequently are places of entrance for decay organisms. Because of the importance of this problem, experimental work was conducted during the 1940 and 1941 seasons in the Crystal Springs, Mississippi, area on causes and methods of prevention of shoulder bruises.

METHODS

The various experimental treatments were applied to green-mature tomatoes immediately after harvesting and the severity of the injury was determined when the tomatoes were ripe. To indicate the degree of bruising, a numerical rating from 1 to 5 was used for the individual tomatoes, a value of 1 indicating slight bruising, 3 moderate bruising, and 5 very severe bruising. Intermediate values of 2 and 4 were also used during the 1941 season. The field boxes (carriers) used in these tests were the standard type used in this area with a capacity of about 75 pounds each. The tomatoes were packed in the standard 30-pound shipping lugs with bulged lids. In regular practice the field boxes are used for hauling the tomatoes from the field to the packing house where the tomatoes are wrapped and packed in lugs for shipment. The parts of the tomatoes undergoing the test were adjacent to the bottom or side of the crate or lug. Practically no shoulder bruising occurred in tomatoes that were not in direct contact with some part of the container. The field crates were hauled in a motor truck over unpaved roads after which the tomatoes were wrapped and held at 72 to 73 degrees F for ripening. The shipping lugs were jolted on an apparatus designed to simulate transit conditions in a refrigerator car (1). Twenty or more tomatoes were used in each test for each treatment. Occasionally, because of loss by decay, it was necessary to obtain records on a slightly smaller number.

RESULTS

Relative Susceptibility of Various Parts of the Tomato to Bruising:—The comparative degree of bruising of the shoulder, side and blossom end of tomatoes is given in Table I, and illustrated in Fig. 1. It will be noted that the shoulder is considerably more susceptible than other portions of the fruit. Bruising on the shoulders is even more serious than the data indicate because of its dark color. Bruising on other parts of the tomato is lighter — generally a buff color.

Causes of Shoulder Bruising:—It can be noted in Table I that bruising caused by dropping tomatoes on a piece of wood so that the

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[1] The author wishes to acknowledge the suggestions offered by D. F. Fisher under whose direction this work was conducted, and the numerous constructive criticisms in the preparation of the manuscript offered by D. H. Rose.

TABLE I—INFLUENCE OF VARIOUS TREATMENTS ON BRUISING OF VARIOUS PORTIONS OF TOMATO FRUITS

Treatment	Degree of Bruising		
	Shoulder	Side	Blossom End
June 20, 1940			
Jolted 72 hours in packed lug, shoulders on bottom, not wrapped	2.60	1.95	0.58
July 2, 1940			
Rubbed on rough board	4.23	2.85	1.96
Dropped 12 inches on wood	0.38	0.44	0
Check, no treatment	0.08	—	—
June 10, 1941			
Rubbed on rough board	3.27	2.00	1.78
Rubbed on smooth board	1.06	0.73	0.33
Hauled 10 miles in field crate, shoulder next to bottom	1.86	1.11	0.82
Dropped 12 inches on wood	0.80	0.55	0.15
Check, no treatment	0.57	—	—
June 13, 1941			
Rubbed on rough board	1.90	1.35	1.75
Rubbed on smooth board	0.58	1.21	1.21
Hauled 10 miles in field crate, shoulder next to bottom	1.06	0.61	1.12
Dropped 12 inches on wood	0.16	0.11	0.11
Check, no treatment	0.22	0.17	0.04
Mean (excluding checks)	1.64	1.17	0.89

shoulder of the tomato made the impact was responsible for only a very small amount of injury. On the other hand, the abrasive action produced by rubbing the shoulder of the tomato on a rough board resulted in a high degree of shoulder bruising (Fig. 2). Rubbing

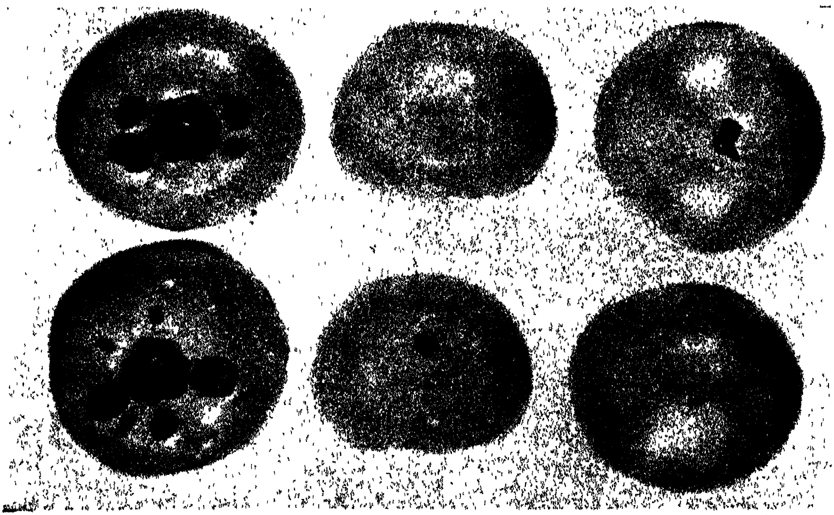

FIG. 1. Relative degree of injury to various parts of tomato fruits. Left to right: Shoulder, side and blossom end.

on a smooth planed board resulted in much less. When tomatoes were hauled in a field box over unpaved roads there was quite a high degree of shoulder bruising when the shoulders were in contact with the rough shook used in making the crate; however, the abrasive action here was less than when the tomatoes were deliberately rubbed on a rough board. Shoulder bruises on green-manure tomatoes are not readily apparent at the time of shipment. However, the injurious effects are noticeable when the tomatoes ripen on the market because the bruised areas not only darken but are frequently places of entry for decay organisms.

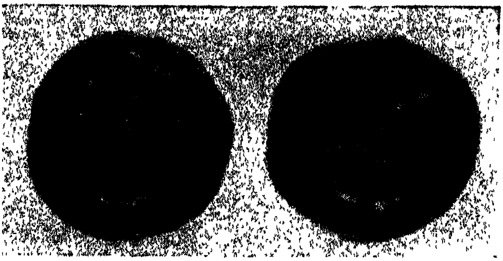

FIG. 2. Shoulder bruising caused by rubbing on a rough piece of board.

Effect of Tightness of Pack:—It has been suggested that shoulder bruises are caused by too tight a pack. To obtain information on this point, a standard 30-pound lug was packed with 6 by 6 size tomatoes. The tomatoes were wrapped and packed in the regular manner, the net weight of the package being 29.9 pounds. Another lug was very tightly packed with 5 by 6 size tomatoes using a 6 by 6 pack. Thus, instead of packing the lug with 90 tomatoes, which is standard for this size, 108 tomatoes were used. The net weight of this package was 37.4 pounds. After packing, both lugs were placed on the jolting apparatus for 48 hours. The shoulder bruising was very slight in both cases, the average being 0.10 in the extremely tight pack and 0.12 in the standard pack.

Effect of Wrapping:—As shown in Table II, the paper wraps used in packing tomatoes were very effective in reducing shoulder bruises in transit. However, tomatoes in field boxes do not have this protection while being hauled from the field to the packing shed.

TABLE II—SHOULDER BRUISING AS INFLUENCED BY WRAPPING

Date of Treatment	Treatment	Degree of Shoulder Bruising	
		Not Wrapped	Wrapped
July 2, 1940	Jolted 72 hours in packed lug	0.64	0.36
June 10, 1941	Jolted 48 hours in packed lug	1.22	0.06
June 13, 1941	Hauled 10 miles in field crate	1.06	0.38

Comparison of Bruising at Bottom and Side of Field Box:—Table III gives the severity of bruising caused by the shoulders being in contact with the bottom of the field box, compared to that caused by the shoulders being in contact with the side of the box. The mean degree of bruising is practically the same in the two cases.

Effect of Roughness of Inside of Crate and Various Protective

TABLE III—SEVERITY OF BRUISING BY SIDE VS BOTTOM OF FIELD BOX

Date of Treatment	Treatment	Degree of Bruising, Shoulder of Tomato in Contact With	
		Bottom	Side
June 24, 1940	Hauled 15 miles over unpaved road	3.89	3.44
June 24, 1940	Hauled 15 miles over unpaved road	3.41	3.28
June 10, 1941	Hauled 10 miles over unpaved road	3.03	3.39
June 13, 1941	Hauled 10 miles over unpaved road	0.48	1.00
	Mean	2.70	2.78

Measures:—As shown in Table IV, shoulder bruising was generally quite severe when the tomatoes were in contact with the rough side or bottom of a field box. Corrugated paper, paper toweling, or excelsior pads were all very effective in reducing shoulder bruises. Fig. 3 illustrates the effectiveness of corrugated paper liners. However, these materials all entail more or less expense and would add to handling difficulties in the field. Placing the smooth planed surface of the box

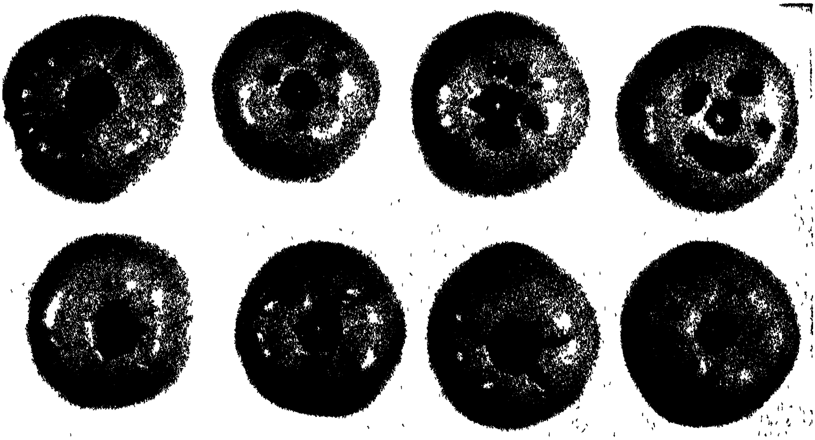

FIG. 3. Tomatoes hauled 15 miles over unpaved road. Top: shoulder in contact with rough shook of field crate; bottom: corrugated paper between shoulder and rough shook.

TABLE IV—INFLUENCE OF ROUGHNESS OF INSIDE OF BOX AND VARIOUS PROTECTIVE MEASURES ON THE OCCURRENCE OF SHOULDER BRUISES

Treatment	Degree of Bruising				
	Jun 24, 1940	Jun 10, 1941	Jun 10, 1941	Jun 13, 1941	Jun 13, 1941
Rough board surface on inside of box	3.89	3.39	3.03	0.48	1.00
Smooth board surface on inside of box	—	1.79	0.81	0.18	0.33
Inside of box lined with corrugated paper	0.46	0.58	0.57	0.28	0.26
Inside of box lined with paper toweling	—	1.10	1.18	0.09	0.11
Inside of box lined with excelsior pad	—	—	0.31	0.18	—

shook on the inside of the field box, although not as effective as some of the other measures, appears to be a practical method of reducing shoulder bruises. Even though many field boxes in the Crystal Springs area are now made with the planed side of the shook on the inside, a great many are so made that the tomatoes are in contact with rough wood and are thus conducive to development of shoulder bruises.

SUMMARY

The shoulder of the tomato is much more susceptible to bruising than are the other parts of the fruit. Although shoulder bruising generally does not appear serious on mature-green tomatoes, it becomes conspicuous on these tomatoes when they ripen. Shoulder bruising appears to be caused by the abrasive action of the rough sides and bottoms of field carriers in contact with the shoulders. The tightness of the pack had little effect on the amount of shoulder bruising. Likewise, dropping tomatoes was a minor factor in causing shoulder bruises. Paper wraps such as are used in packing tomatoes in lugs were effective in reducing shoulder bruises in transit. The use of field boxes that had the smooth planed side of the shook on the inside was an effective practical means of reducing shoulder bruises, and lining the box with corrugated paper, paper toweling or excelsior pads caused an even greater reduction.

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Sand Culture Studies of the Effects of Various Concentrations of Added Salts Upon the Composition of Tomato Plants

By Robert F. Wall and E. L. Hartman, *Oklahoma A. & M. College, Stillwater, Okla.*

PREVIOUS work at this Station (1, 2, 3, 4) has outlined the toxicities of the salts commonly contaminating Oklahoma waters to several typical greenhouse plants, and applications of the results so far attained to the economically important problems of reduction or alleviation of toxic effects have been suggested.

This study further attempts to define the effect of these same waters upon the accumulation in the plant of several of the inorganic elements essential to both plant and animal nutrition and to interpret these effects as they are involved in the mechanism of salt toxicity, and in relation to their significance as factors in animal nutrition.

Procedure

Marglobe variety tomatoes were transplanted to fine quartz sand in 6-inch clay pots when 4 inches in height and watered with a nutrient consisting of 9 milliliters of 0.5 molar $MgSO_4$, 9 milliliters of 0.5 molar KH_2PO_4, 12 milliliters of 0.5 molar $Ca(NO_3)_2$, 1 milliliter of 4 per cent ferric citrate, and 1 milliliter of an A–Z solution according to Haas (5) per liter, to which solution the experimental salt was added. Each experimental unit consisted of a group of five plants. All plants were spaced to provide uniform environmental conditions. The sand in each pot was leached with cistern water at weekly intervals to minimize salt accumulation. The quantities of solution used were noted and the condition of the plants recorded by observation of the appearance and intensity of characteristic toxicity symptoms during, and by Kodachrome photographs at the termination of the experiment. The plants were then clipped at ground level, the groups weighed green,

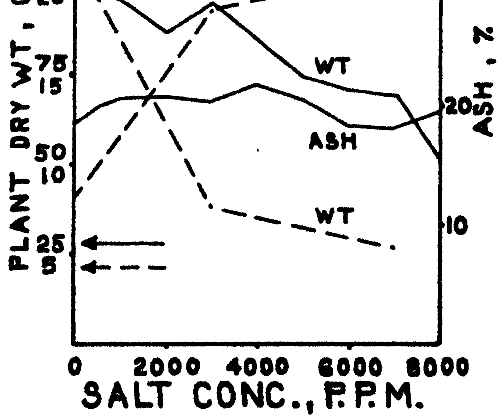

Fig. 1. Effect of temperature on Na_2SO_4 toxicity.

dried, reweighed, and ground through a 0.5 millimeter screen in a Wiley mill in preparation for analysis. Ash, Ca, Mg, Mn, P, N, and S were determined according to the methods of the A.O.A.C. (6), Na according to the method of Barber and Kolthoff (7), K by the method of Wilcox (8), and Cl as directed by Caldwell and Moyer (9). It would have been desirable to have determined Fe, but this was precluded by grinding through the steel Wiley mill, necessitated by the impracticability of handling the large number and size of samples on an iron-free basis. The analytical results have been presented graphically to facilitate recognition of significant variations.

It is generally accepted that salt accumulation by plants parallels respiratory and transpirational processes, although the mechanism of the whole is obscure. This view is presented in the review by Steward (10), and later work has affirmed that a high transpiration rate increases mineral absorption (11), and that a high or low humidity decreases or increases salt absorption in parallel with the effect in decreasing or increasing transpiration (12, 13). As salt accumulation is a process involving aerobic respiration, which will be accelerated by increased temperatures, as will the rate of transpiration, it is evident that salt accumulation should be markedly influenced by the two-fold effect of temperature upon these factors. Zamfiresque confirms this in reporting the absorption at 30 degrees C of K 9 times, of P 8 times, and of Ca 2 times the absorption at 4 degrees C (14). Ahi and Powers (15), in a study of the influence of temperature on the salt tolerance of several roughage crops utilizing both culture and field experiments, report that at 55 degrees F germination and growth were much better than at 75 degrees F.

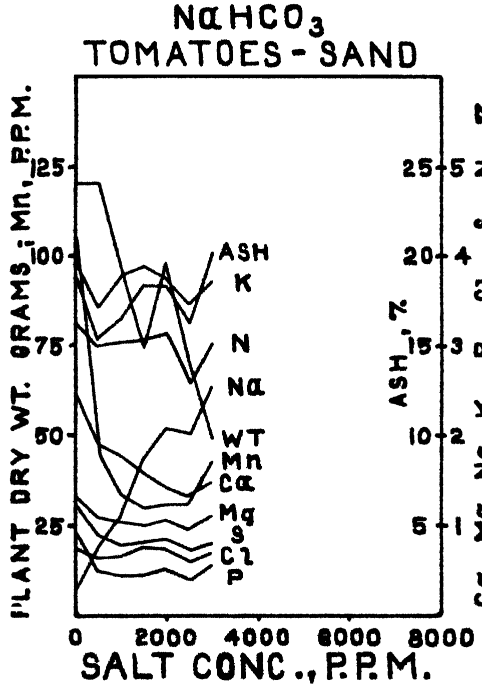

FIG. 2. Effect of NaHCO₃.

A comparison of this and preceding investigations at this station emphasizes the effect of factors affecting transpiration and respiration in modifying salt injury to tomatoes. Previous studies were, for the most part, conducted during the summer months with the average daily temperature 90 degrees F or above, the night temperature correspondingly high, sunlight intense, days long, and with the

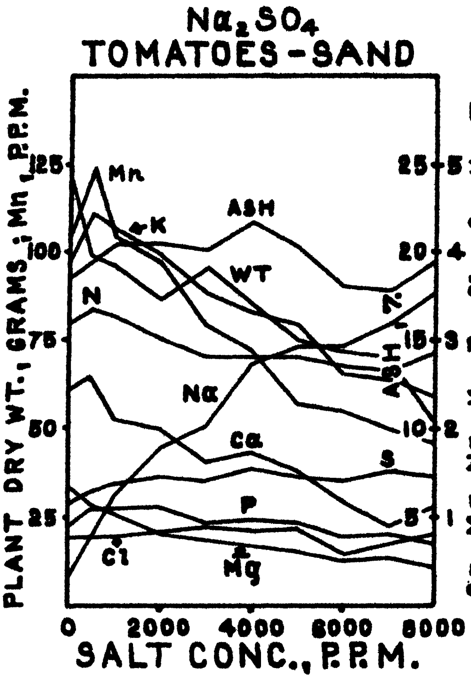

FIG. 3. Effect of Na_2SO_4.

humidity low. This experiment continued from October 1, 1940 to February 1, 1941, and coincided with an unusual extended period of cool damp weather. The temperature seldom exceeded the maintained figures of 75 degrees F during the day and 60 degrees F at night. Sunlight was moderate and frequently obscured, days were short, and the humidity was very high. Fig. 1 graphically compares plant dry weight and ash for increasing concentrations of Na_2SO_4 at the two extremes mentioned. This is admittedly not a quantitative comparison, but the qualitative significance in the slope of the lines is a positive indication of the important influence of temperature, light, and humidity in salt toxicity.

Due to the low toxicity apparent and slight change in total ash caused by the high concentrations of salts used, the effects of these salts upon the relative proportions of nutrient elements absorbed are the most obvious results. The observations for the five salts used, $NaHCO_3$, Na_2SO_4, $CaCl_2$, $MgCl_2$, and $MgSO_4$ are recorded graphically in Figs. 2 to 6.

Fig. 2 illustrates the

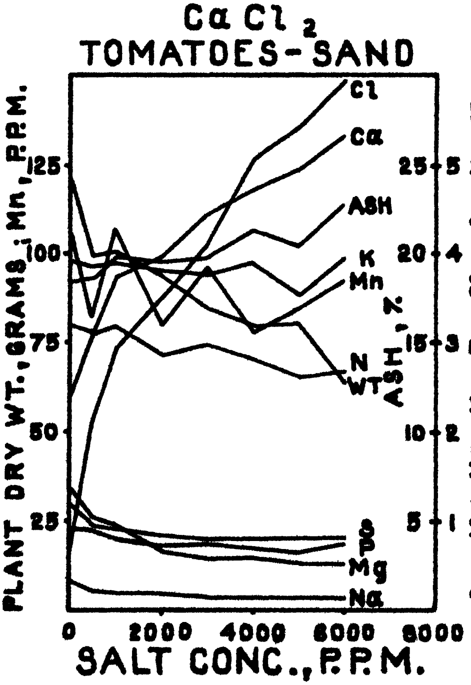

FIG. 4. Effect of $CaCl_2$.

effect of $NaHCO_3$ in reducing plant growth as evidenced by plant dry weight and the curtailed absorption of most ions, except that of Na, which is increased eight-fold. The decreased absorption parallels the increased pH induced in the nutrient media by the added $NaHCO_3$, and the toxicity is undoubtedly due to the high ionic concentration, the direct distorting effect upon the metabolism of the root system of the alkalinity of the solution, and the consequent reduced availability of many essential nutrients. Mn content is reduced to one-third, P to one-half, and Ca and S to two-thirds the normal values, with no significant variation in total ash. The absorption of several of the essential trace elements from alkaline solution may be expected to be reduced to a degree equal to or greater than that of Mn, as many of them readily form exceedingly insoluble complex salts, of which the basic phosphates are an example.

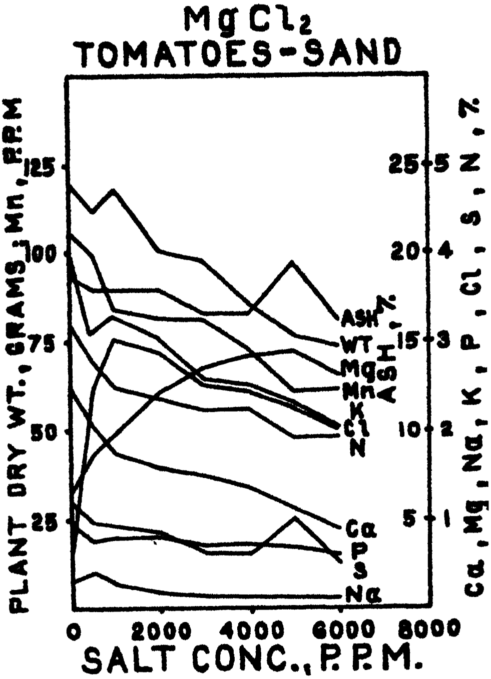

FIG. 5. Effect of $MgCl_2$.

As evidenced by the reduction in dry weight and the general appearance of the plants the order of toxicity was $NaHCO_3 > MgCl_2 > CaCl_2 > Na_2SO_4 > MgSO_4$. This series parallels the ratio of the numbers of ions per equal weight concentration of these salts. The Avagadro numbers of ions contained in 1,000 parts per million of the respective salts are: 0.0357, 0.0315, 0.0270, 0.0211, and 0.0167; that is, the greater the number of potential ions the greater the toxicity. This lends additional significance to the factor of osmosis in the relative toxicity of a salt to tomato plants.

Certain of the toxicity effects characteristic of the various ions were evident. All chloride salts showed a typical yellow chlorosis, and $MgSO_4$ caused a dark green foliage.

The toxicity due to the high pH supercedes the toxic effects of a high ionic concentration with $NaHCO_3$; with the other salts used, osmotic and other concentration effects, and the nutrient unbalance due to an excessive proportion of certain ions appear the principal toxic factors, modified by the pH of hydrolysis of the added salts. With Na_2SO_4, $CaCl_2$, $MgCl_2$, and $MgSO_4$, and also with $NaHCO_3$, the per cent of the added ions increases, while the per cent of other ions is depressed in rough parallel with the decrease in dry weight. The explanation of the variations in the effects of the different ions and the irregularity of the curves obtained is probably that the plant adsorbing entity is a correlation of delicately balanced colloidal systems. Relatively minor changes in the effective concentration of one or several ions, either due directly to an added salt, or secondarily to the effects of the added salts upon the ionization, solubility, or complex formation of other salts present may produce a considerable distortion of the mechanism for salt absorption and a consequent marked effect upon the plant ash and its composition. An analogous sensitivity to relatively small changes in the nutrient ratio, and the anomaly that nutrient solutions of radically different composition may give very similar results, observed in experiments to establish an optimum nutrient, demonstrate that salt absorption, and therefore salt toxicity, cannot be explained adequately as a function of ionic and nutrient concentration alone, but require consideration of the essentially colloidal mechanism of absorption as the basis of approach to an understanding of the problem.

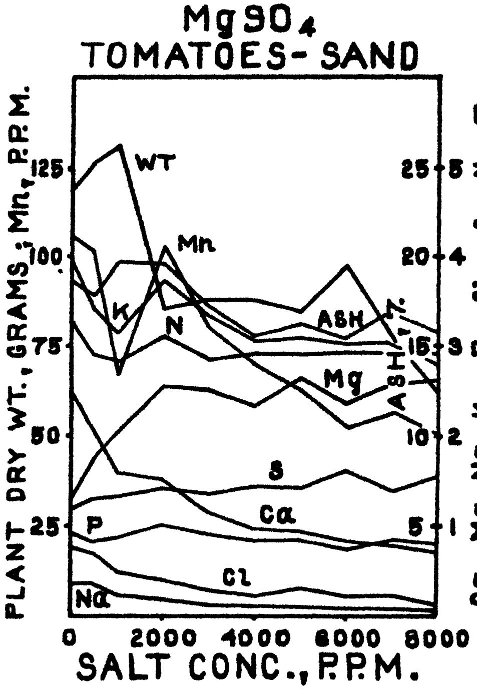

FIG. 6. Effect of $MgSO_4$.

Added Na and Cl ions increased and Ca, Mg, and SO_4 ions decreased the absorption of other ions in this experiment, as evidenced by the graphs obtained, in accord with the accepted effects of these ions upon the permeability of the plant cell membrane. It is also noted that the alkaline $NaHCO_3$ solutions are particularly effective in increasing permeability, absorption, and therefore toxicity.

Many nutritional deficiencies of both animals and humans have been traced to mineral deficiencies in the soil in which the food is grown (16), and it is generally accepted that there are many areas of general sub-clinical deficiency in the United States. From an examination of the graphs it seems evident that irrigation with salt contaminated waters may cause the production of food materials of reduced content of Ca, P, and Mn, plus other nutritionally essential elements not determined in this study. In case of a low soil supply of a nutrient element, and/or supplementary food materials of low content, this might be instrumental in causing deficiency effects, either clinical, or subclinical as evidenced mainly by reduced vigor and health.

In all cases the N content is reduced; although not always markedly, it indicates a general reduced nutritive value induced by salt contaminated waters, and that, in addition to reduced production and possible mineral deficiencies, the feeds so grown will probably be of inferior market grade.

It is significant that the greatest effect of ion reduction occurs with the first increments of salt addition, and it should be noted that alkaline $NaHCO_3$ solutions are particularly effective, with several curves breaking sharply at low concentrations.

SUMMARY

The coordinated effects of temperature, light, humidity, transpiration and respiration as they influence salt absorption must be considered in adequately defining salt toxicity, as salt absorption, and therefore salt injury, parallels the transpirational and respirational processes of the plants, and the variations so produced are very large.

Salt toxicity is apparently due to the high ionic concentration, reduction in availability and/or absorption of other ions, and the effect of the induced pH. The pH toxicity exceeds the other toxic factors with $NaHCO_3$; with other salts the pH effect is subordinate.

The greater the number of potential ions for equal weight concentrations of the salts used the greater the comparative toxicity of the respective salts to tomato plants.

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Wheel Injury to Tomatoes During Spraying and Dusting Operations

By John D. Hartman and R. W. Samson, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

EXPERIMENTS were carried out in the seasons from 1938 to 1941 inclusive, to determine the possible profit, if any, to be derived from spraying or dusting cannery tomatoes in Indiana for the control of leaf and fruit diseases. Conventional types of commercially available row-crop sprayers and dusters were used. The design and operation of the 1941 experiment were such that the authors were able to obtain data permitting a close estimate of the losses of marketable tomatoes caused by injury from the wheels of the machines. Such information is of value in analyzing the costs of disease control and calculating the relative efficiency of spraying and dusting machines equipped with booms covering various numbers of rows.

Concern over possible injury to cannery tomato vines from the wheels of spraying and dusting machines has led some commercial operators of sprayers in particular, to use very long booms, covering as many as 19 or 20 rows. The machines are driven down the rows that are later run over by the trucks and wagons used to haul out the harvested tomatoes. It is uncertain, however, whether such machines may be as practical as smaller equipment.

Experimental Layout and Operations

Spray and Dust Treatments:—The experiment involved six different spray and dust treatments as follows:

1. Insoluble copper spray, all season.
2. Bordeaux mixture spray, all season.
3. Insoluble copper dust, all season.
4. Insoluble copper spray, delayed.
5. Bordeaux mixture spray, delayed.
6. Insoluble copper dust, delayed.

All season treatments were applied July 5, 19, and 28, and August 7 and 22; delayed treatments at only the last two of these dates. Each treatment was replicated five times, making a total of 30 plots from which data on wheel injury were obtained.

Arrangement and Planting of Plots:—The experiment was laid out in five tiers of randomized plots, each tier being 125 feet wide, with a 25-foot unplanted strip between tiers and at the ends of the field to permit maneuvering of the machines. The plots were thus 125 feet long. The plant rows were spaced 3½ feet apart, with eight rows in each sprayed plot and 12 in each dusted plot. Records were taken only on the middle six rows of each plot.

The soil of the experimental field was a Crosby or light colored silt loam in the higher parts and a Brookston or dark silt loam in the slight depressions. The plots were set with Georgia-grown Indiana Baltimore tomato plants on May 21 and 22, and were fertilized and cultivated according to usual horticultural practice. By the time the second applications of the first three treatments were made on July 19 the vines had already met between the rows in most parts of the field. Growth after that date was limited because of drought, but plant size was typical of rather good fields in Indiana. The vine growth was not as rank, however, as on some of the dark soils of the Kokomo-Elwood-Frankfort area of the state.

Spraying and Dusting Equipment:—The sprayer used was a tractor-drawn, power take-off rig mounted on rubber-tired wheels and equipped with 300-gallon tank, 8-row boom, and three nozzles to each row. The duster was a 6-row outfit, with two nozzles to the row. It was mounted on steel-rimmed wheels and was equipped with a separate engine for its blower. It was drawn by the same tractor that was used for the sprayer. The tractor (Fig. 1) was rubber-tired, the drive wheels being spaced to straddle two rows. The closely spaced front wheels of the tractor ran between these two rows. The wheels of the sprayer and duster were spaced to track behind the drive wheels of the tractor.

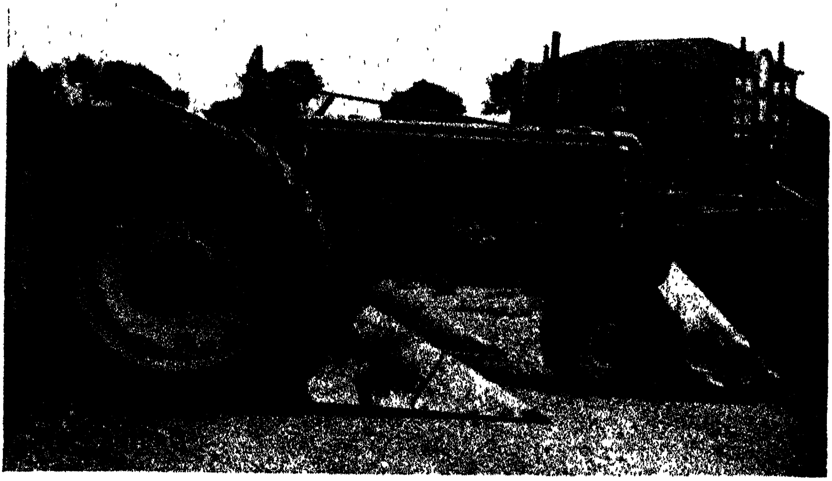

Fig. 1. Tractor equipped with vine shields. The vine shields have been lowered, as for use in the field.

Special vine shields were built for each wheel of each machine (Fig. 1). They could be raised and lowered by operators on the machines and could be set to drop into a fixed position about an inch above the level of the ground. All the shields, except the front one on the tractor, were sufficiently tapered that the points showed no tendency to dig into the ground. They were not equipped with frontal supporting rollers as were those used by Whipple and Walker (1). Their chief defect may be in having insufficient strength to withstand sidewise stresses applied near the points.

Measurement of Wheel Injury:—All eight rows of each sprayed plot were covered by one passage of the rig through the plot. Records were taken only on the inner six rows. Of these the two outermost were not injured by wheels, the next two were injured on one side only, and the two innermost rows were injured on their inner sides by the front wheel of the tractor and on the outer sides by the drive wheels and the wheels of the sprayer.

It required a forward and return passage of the six-row duster to cover the 12 rows of each dusted plot. Records were likewise taken only on the inner six rows. In this case, however, the two innermost rows received no wheel damage, the next adjacent rows were injured on one side, and the two outer rows of the six were injured on both sides.

Since the yield data were taken separately on each of the six inner rows of each dusted and sprayed plot it was a simple matter to determine, with considerable accuracy, the amount of injury attributable to the wheels and associated with vine shields. Data were available from 30 individual rows receiving each fungicide treatment. Ten of these rows were not injured, ten were injured on one side only and ten on both sides.

Harvesting of Plots and Analysis of Yield Data:—Harvesting of the plots began on August 12 and ended on October 13. Only fruits grading U. S. No. 1 or U. S. No. 2, according to the grades for canning tomatoes, were picked.

Initial analysis of the data showed that there were no significant differences in yield among the plots receiving the various spray and dust treatments, although most of them slightly outyielded the check. The data were then anlyzed by comparing the yields of the injured and uninjured rows receiving a single spray or dust treatment. Then, the data from all but the check plots were combined and analyzed for variance due to single fungicide treatments and to groups of treatments, for variance due to wheel treatments, and for variance due to interactions between fungicides and wheel treatments.

RESULTS OF THE EXPERIMENT

Performance of the Vine Shields:—It was quite obvious that the vine shields greatly reduced damage from the wheels of the machines. However, some branches were run over and some fruits were knocked off. This was particularly true when, late in the season, fruit clusters far out on the stems hooked on branches in adjoining rows. Furthermore, at the time of the last two fungicide applications it was difficult for the tractor operator to see to steer between the rows. This was true in spite of the fact that the machines were always run in the same direction through a plot in making successive applications. The earlier spraying and dusting operations had little effect in training the vines parallel with the row, out of the way of the shields and wheels later on.

Effect of Wheel Injury on Yield:—The data showing the effects of wheel treatments are summarized in Table I. It is apparent from this table that wheel injury caused some loss in yield. The interaction between spray treatments and wheel injuries was found to be exceed-

TABLE I—EFFECT OF WHEEL INJURIES ON YIELD OF TOMATOES

Spray or Dust Treatment	Average Yield for Rows Injured as Indicated					Differences for Significance at 5 Per Cent Point (Tons Per Acre)
	No Wheel Injury (Tons Per Acre)	Wheel Injury on One Side		Wheel Injury on Both Sides		
		Tons Per Acre	Per Cent of Uninjured Rows	Tons Per Acre	Per Cent of Uninjured Rows	
Sprays all season	12.3	11.9	97	11.6	95	N.S.*
Delayed sprays	11.8	11.9	101	10.9	93	0.6
Dust all season	12.8	11.1	87	10.9	85	1.1
Delayed dust	13.1	11.4	87	12.0	92	N.S.
Sprays or dust all season	12.5	11.6	94	11.4	92	0.8
Delayed sprays or dust	12.2	11.7	96	11.3	92	0.7
Sprays all season or delayed	12.0	11.9	99	11.3	94	0.6
Dust all season or delayed	13.0	11.3	87	11.5	88	0.9
Sprays or dusts all season or delayed	12.3	11.7	95	11.4	92	0.5

*N.S. means no difference significant.

ingly small and statistically insignificant; so the data for the two spray materials were combined. The interaction of wheel injury and period of application of wheel injury and period of application of fungicides is likewise insignificant.

The interaction of wheel injury and type of fungicide distributor was significant. Evidently, the duster wheels and vine shields were more injurious than those of the sprayer, although no marked difference in plant injury from the two machines was noticed in the field. The greater injury caused by the duster may have been due to its steel-rimmed wheels, which perhaps cut off more branches than did the rubber tires of the sprayer. It is more likely that the vine shields on the duster were not as well designed as those on the other machines.

SUMMARY

Wheel damage to tomatoes during spraying and dusting operations resulted in an average reduction in yield of 5 per cent on rows which were injured on one side only, and an average of 8 per cent on rows which were injured on both sides. All wheels were equipped with vine shields.

The degree of injury was about the same whether the plots were sprayed or dusted five times during the season or received only two delayed applications.

The data indicate that, when the total yield from all rows covered by the boom is considered, the average reduction in yield for a 6-row sprayer was 2.3 per cent. For 8, 10 and 20-row outfits it would have been 1.8, 1.4, and 0.7 per cent, respectively.

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Experiments in Plowing Under Coarse Organic Matter for Tomatoes

By John D. Hartman and Edw. C. Stair, *Purdue University, Lafayette, Ind.*

THE comparatively light colored Crosby silt loam and silty clay loam, principal tomato soils of central Indiana, rarely produce as well as the darker Brookston silty clay loam with which they are associated. Large applications of commercial fertilizer have failed to modify this relative productivity to any extent. Some of the difference between the soils of the two series may be attributable to the fact that the Brookston always lies in small depressions and presumably has a higher water table than the Crosby; but, doubtlessly, difference in amounts of organic matter accumulated over the ages is at least equally important. The surface soil of the Crosby series characteristically contains 2 to 3 per cent organic matter, whereas the corresponding figures for Brookston are 5 to 8 per cent. Crosby subsoils are frequently mottled in color and must therefore be poorly aerated during parts of the year.

With these facts in mind, it seemed desirable to try plowing under large quantities of coarse organic matter on Crosby silt loam in an attempt to loosen it up and so improve its productivity. Experiments were run in 1939 to determine the effect of cornstalks on tomato yields, and in 1939 to 1941, to determine the effect of green manure crops.

1939 Cornstalk Experiment

In 1939 an area 170 feet by 140 was divided into seven plots each 20 by 170 feet. On plots 2, 4, and 6 dry cornstalks, collected from nearby fields, were plowed under at the rate of 10,000 pounds per acre. These were laid in the furrow bottoms as the plowing progressed. On them was sprinkled enough sulphate of ammonia, 475 pounds per acre, to give the added material a carbon-nitrogen ratio of 20 to 1. Plots 1, 3, 5, and 7 received no cornstalks or nitrogen, but were plowed on the same date, June 7, 1939. The whole area was nearly bare during the preceding winter and had been uniformly planted to soybeans in 1938 and to tomatoes in 1937.

The day after plowing, Indiana Baltimore plants were set on these plots in rows 5 feet apart. They were fertilized at the rates of 20 pounds of nitrogen, 100 pounds of phosphorus pentoxide and 80 pounds of potash to the acre. All fertilizer applications in the experiments reported in this paper, except the applications of sulfate of ammonia alone, were in bands 3 or 4 inches deep along the rows.

During the season the plants made fairly vigorous growth for this soil type, except in the south side of the field, plots 6 and 7, where there was much injury due to water which stood on the soil. The plants on plots which had received cornstalks and extra nitrogen at the rate of about 95 pounds per acre were, for a while, darker green than the plants on the check plots. Later the plants on all plots became badly defoliated and yields were reduced from this cause. Only marketable fruits were picked. The harvest period extended from August 31 to October 3, 1939.

Plowing under cornstalks and nitrogen had no significant effect on yield. With the cornstalks 5.3 tons per acre were obtained; without them 5.2 tons.

GREEN MANURE AND COVER CROP EXPERIMENTS

Also in 1939 a green manure experiment was laid out on Crosby soil which had been in tomatoes in 1938 and in soybeans the year before that. There were three treatments, each in triplicate on plots 20 by 120 feet arranged in randomized blocks:

1. *Pearl Millet Green Manure:*—Pearl millet planted June 9, at the rate of 16 pounds per acre, in rows 3 feet apart; plowed under October 16.
2. *Corn Green Manure:*—Hybrid corn, planted June 9, at the rate of 53 pounds per acre, in rows 3 feet apart; plowed under October 16.
3. *Harvested Corn:*—Hybrid corn planted June 9, at the rate of 8 pounds per acre in hills 3 by 4 feet. Stalks and fodder removed from the plots.

All treatments were fertilized with nitrogen, phosphoric acid, and potash at the rates of about 20, 25, and 40 pounds respectively per acre. The pearl millet plots produced about 9,200 pounds of dry matter per acre and the corn green manure plots 11,700 pounds. From the harvested corn plots were removed nearly 7,000 pounds of dry matter, which included about 70 bushels of good corn per acre. At the time of plowing sulfate of ammonia was scattered over the ground at the rate of 436 pounds per acre on the pearl millet plots and 552 pounds per acre on the corn green manure plots. These nitrogen additions were calculated to be sufficient to bring the carbon-nitrogen ratio of added material down to 20 to 1. Since the green manures were rather thoroughly mashed down by large tractor wheels prior to being turned under, the added sulfate of ammonia must have lain in close proximity to the organic matter within the soil. All plots were then sown with rye.

The rye was plowed on May 8, 1940, when it was 13 to 26 inches tall. At both the fall and spring plowings furrows were made 9 to 10 inches deep. All plots were then set with wilt resistant selection 129 of the Indiana Baltimore variety on June 19 and fertilized at the rate of 75 pounds of nitrogen, 110 pounds of phosphoric acid and 55 pounds of potash per acre.

Growth was definitely vigorous for Crosby silt loam, but on account of the lateness of the strain of plants and the delayed setting, frost killed the plants before they had matured many of their fruits. However, on account of the necessity of saving seed from these plots total yields of all nearly mature fruit were obtained. Picking began on September 26 and ended November 7.

The same experiment, with one additional treatment was repeated in 1940–1941 on a third area. This ground had been in tomatoes in 1939 and in sweet corn in 1940. It differed from the soil of the previously discussed experiments in that it had received a manure application, about 8 tons per acre, during the winter before the green manures were sown. Plots were in this case 18 feet by 175 feet and were replicated four times.

The added treatment was like treatment 3 of the 1939–1940 experiment except that it included no winter cover crop of rye preceding the tomatoes.

The dates of planting the green manures and the harvested corn crop were June 6 and 7, 1940. The crops were fertilized at the rates of approximately 15, 20, and 35 pounds per acre of nitrogen, phosphoric acid and potash, respectively.

During the drought of 1940, the pearl millet produced only 5,500 pounds of dry matter per acre, the corn planted thickly 7,000 pounds and the harvested corn 6,500 pounds. The thickly planted corn and the millet were plowed under, with the usual additions of nitrogen, on October 22 and 23, 1940. All plots, except those of treatment 4, were sown to rye the following day.

When the rye was about 22 inches tall, on May 15, 1941, it was plowed under. On June 18 to 21 the west end of each plot was set with wilt resistant selection 129 and the east end with the regular strain of Indiana Baltimore. The plants were again spaced in rows 5 feet apart and were fertilized with about 60 pounds of nitrogen per acre, 90 of phosphoric acid, and 60 of potash.

As in 1940, growth of vines was vigorous, at least at the southern end of the experiment. Only marketable tomatoes were picked, the harvest period lasting from September 11 to October 20. Frost terminated picking when there remained on the ground about 3 or 4 tons of nearly mature fruit to the acre.

Yield records for both green manure experiments are summarized in Table I. None of the differences between treatments is significant, even when the data for the two years are combined. The differences which were found indicate a detrimental, rather than a beneficial, effect of plowing down large amounts of coarse organic matter. On the other hand, there is some indication that the use of rye as a winter cover was beneficial. Further data of similar kinds are needed.

TABLE I—EFFECT OF GREEN MANURES AND A WINTER COVER CROP ON YIELDS OF TOMATOES

Treatment	1939–1940 Experiment (Tons Per Acre)	1940–1941 Experiment (Tons Per Acre)
Pearl millet green manure-rye in winter	8.5	7.1
Corn green manure-rye in winter	9.3	7.4
Harvested corn—rye in winter	11.5	7.6
Harvested corn—no rye in winter	——	6.5

DISCUSSION

Bushnell (1) has published experimental results showing marked increase in yield of potatoes from plowing under large quantities of coarse organic matter with nitrogen. His data are for 5 years, but with only a single plot of each treatment each year. The benefits derived were evidently attributable to improved soil aeration. There are some indications that tomatoes are somewhat less susceptible to injury caused by poor aeration than are potatoes and, of course, the Wooster silt loam of Bushnell's experiments is doubtlessly very different from Crosby silt loam in spite of many superficial similarities. Purvis and Blume (2), Smith and McCubbin (3), and others also report increases in yield from plowing under summer green manures for potatoes.

SUMMARY

Preliminary investigations indicate that the addition to Crosby silt loam of large quantities of organic matter and sufficient nitrogen to make a 20 to 1 carbon-nitrogen ratio in the added material failed to increase yields of tomatoes. This was true when the organic matter was added to the soil in the spring when plowing for the tomatoes and when it was grown on the ground as a green manure in the summer before the tomato crop was raised.

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The Influence of Irrigation Water on the Yield and Quality of Sweet Corn and Tomatoes with Special Reference to the Time and Number of Applications

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THE moisture supply in many areas in the southwest is at times unfavorable to the production of truck crops such as sweet corn and tomatoes. At Stillwater, Oklahoma, for example, the average rainfall for April is 4.02 inches, 5.02 for May and 3.95 and 2.66 inches respectively for June and July. Tests with several vegetable crops conducted on a sandy loam soil at the Oklahoma Experiment Station farm have demonstrated that an irrigation supplement is frequently of great benefit. Because some growers can develop but a limited supply of water for irrigation, studies are being conducted to determine ways to utilize this limited supply to best advantage in vegetable production. The water is applied to the crops in furrows and as an overhead spray from a Skinner line.

Sweet Corn

The 1940 and 1941 crops were drilled in rows April 12 and 15 respectively placing about 600 pounds of 5–10–5 fertilizer at the same time. Four treatments were arranged in Latin squares with two 86 foot rows per plot separated by single buffer rows. A 6-foot area between the blocks allowed for cross-furrows to collect the water from the plots of the first block and to redistribute it to the proper plots in the next block. The variety Country Gentleman was planted in 1940, Golden Colonel in 1941.

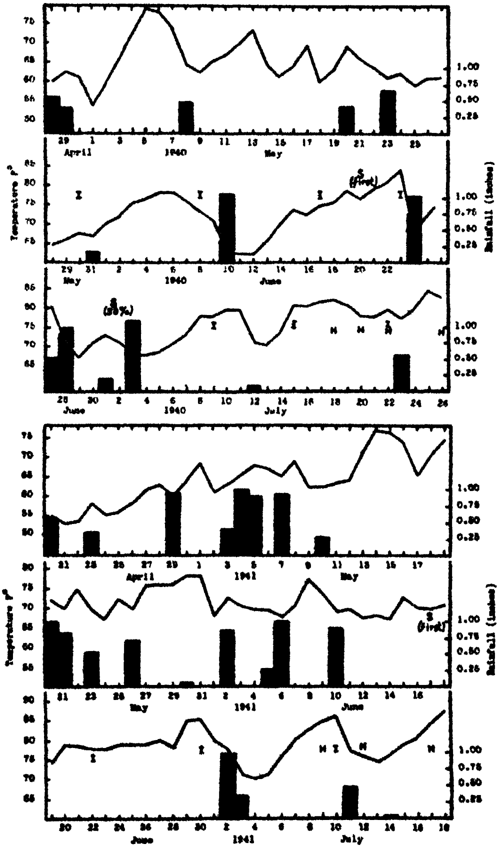

Fig. 1. Mean temperature and rainfall for the 1940 and 1941 seasons in relation to the sweet corn crops. Irrigation dates are indicated by "I", harvests by "H", and silking dates by "S".

The irrigations were applied as appeared desirable with reference to the moisture supply derived from rainfall. A maximum of seven applications were made in 1940, three before silking began, one during the silking period and three during the post-silking period. With more rainfall in May and early June in 1941 only the three post-silking irrigations were applied (see Fig. 1 for rainfall data and irrigation dates). Soil moisture data were secured by the resistance method (1) in 1941 for locations between the plants in the row and between the rows at a depth of 7 inches.

Silking data secured in 1940 indicated that the three pre-silking irrigations advanced the average silking date by 1 day, and observations indicated some increase in plant development. According to the 1940 data in Table I, these early irrigations had no significant effect on the yield of green ears. Thus the plots irrigated in the post-silking period only, were as productive as those irrigated before and after silking, while the yield for the unirrigated plots was not significantly different from that of plots receiving irrigations prior to silking only. Wider differences are found when the yields of Number 1 ears are considered since the late irrigations increased the proportion of the Number 1 ears. These results suggest that the irrigation supplement was of most value during the time the ears were developing even though the rainfall was more deficient earlier in the season, since that for May was 3.30 inches below the average as compared to a deficit of but 0.70 inch for July. Precipitation for June was 1.38 inches above the average.

TABLE I—YIELD AND QUALITY IN SWEET CORN IN RELATION TO CERTAIN IRRIGATION TREATMENTS FOR THE 1940 AND 1941 SEASONS

Irrigation Treatments	No. of Irrigations	Yield Ears†		No. 1 Ears		Ear Averages	
		Lbs Per Plot	Tons Per Acre	Tons Per Acre	Per Cent	Weight (Lbs)	Length (Ins)
		1940 (Country Gentleman)					
Irrigated entire season*	7	147	6.45	5.34	86	0.63	6.95
Irrigated after silking...	4	153	6.23	4.98	85	0.61	6 75
Irrigated before silking..	3	121	5.05	4.34	77	0.61	6.65
Not irrigated........	0	118	4.94	3.96	70	0.59	6.68
		1941 (Golden Colonel)					
Irrigated June 22, 30 and July 10	3	108	4.09	3.48	85	0.56	—
Irrigated June 22 and 30	2	102	3.88	3.34	86	0.56	—
Irrigated June 22......	1	86	3.28	2.64	81	0.52	—
Not irrigated	0	70	2.67	2.12	80	0.51	—

*See Fig. 1 for irrigation dates and weather data.

†A difference of 17.4 pounds per plot in 1940 and 18.5 pounds in 1941 is required to be significant.

With ample rainfall in May and early June of the 1941 season the irrigation was delayed until the plants had commenced silking. As indicated in the yield data in Table I the most practical treatment that season was two irrigations applied on June 22 and 29. A third irrigation made July 10, after the first harvest, caused a slight but insignificant increase in yield. The difference in yield between the unirrigated plots and those receiving but one irrigation on June 22 was greater (0.61 ton on acre basis) but lacked a little of being statistically significant.

Soil moisture data for 1941 indicated that the moisture in the row was quite low before the first irrigation was applied on June 22, (Fig. 2)[1]. A rain of 1.33 inches on July 1 and 2 brought the moisture supply of the unirrigated plots up above the wilting range for about a week. The moisture level in the soil between the rows was higher than that in the row, suggesting a greater concentration of roots near the plants in the row. This moisture data indicated that rainfall was more readily absorbed by the soil of the unirrigated plots. Apparently there was more run-off in the case of the irrigated plots. It was not practical to recondition the soil by cultivating late in the season.

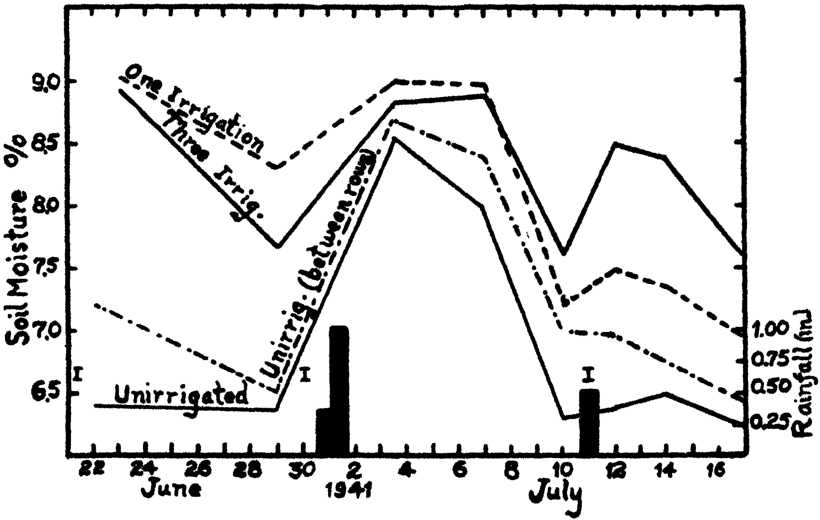

FIG. 2. Soil moisture data secured at a depth of 7 inches in the row (between plants) for plots unirrigated, irrigated one and three times, and for unirrigated plots at the same depth between the rows. The dates irrigations were applied are indicated by "I" and the rainfall as inches is indicated by the vertical bars.

It is worthwhile to note that the two seasons covered by this test were the most favorable for corn production (without irrigation) in a 5-year period beginning with 1937 as indicated by yields secured for Golden Cross Bantam as grown in variety trials on the farm. During 1940 and 1941 yields of approximately 5 tons of marketable ears per acre were secured for this variety. Yields of 3.1, 2.8, and 2.1 tons per acre were secured for 1937, 1938, and 1939 respectively.

TOMATO STUDIES

Fruit production in the Oklahoma tomato crop is limited at times by certain climatic factors as has already been described by Radspinner (2) and Smith (3). It appears that high temperatures is the principal factor limiting fruit set although low humidity and a lack of soil moisture appear to be associated factors. Since the yield is affected by the size of the plant or the total bearing area as well as the proportion of flowers setting fruit, it seems that the use of irrigation water with tomatoes in Olkahoma should be of practical value.

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[1] The average wilting percentage for a soil from an adjacent experimental area was 6.8 when determined with snap bean plants. The moisture equivalent was 13.0 per cent when determined by the suction method.

A number of irrigation tests have been conducted with tomatoes in which fruit set data were secured along with the usual yield records. From two to five varieties were planted in replicated plots in these tests but in the present paper only the combined results are to be presented. To secure data on fruit set, a suitable number of clusters with their first open flower were tagged at intervals throughout the main blooming season. The plants were set 4 by 4 feet with about 600 pounds of 5–10–5 fertilizer placed in the row. Irrigation water was applied by means of furrows except for one series of plots which was irrigated with a Skinner line. In most tests the irrigations were applied as was thought necessary to supplement the natural moisture supply.

A preliminary test with a crop produced during a characteristically dry fall season in 1938 indicated that irrigation (by furrows) was favorable to fruit set. An average set of 28.7 per cent was secured for irrigated plots as compared to 15.1 per cent for unirrigated ones.

In a test with a crop planted in the spring of 1939 the quantity of water applied in each irrigation was varied with four series of plots by varying the time of the "soaking period", after the water had completed the run through the furrows which were 330 feet long. The water was applied at intervals of 7 to 12 days throughout the growing season, and an effort was made to thoroughly irrigate the first series with decreasing amounts of water applied to the other three irrigated series. Four sets of clusters were tagged, the first on June 8, the last on July 8 and four varieties were planted.

The results of this test indicated that the average fruit set of 35.0 per cent for the unirrigated plot was significantly higher than that for any of the irrigated series where a set of 25.5 per cent was secured for the series receiving the smallest amount of water and increased to 28.8 per cent for the series most thoroughly irrigated. The actual yields of fruits for the two series of plots receiving the smaller amounts of water were not significantly different from the unirrigated series which yielded at the rate of 2.0 tons per acre. The yield for the two remaining irrigated series was significantly higher at about 2.6 tons per acre. Apparently the applications of water stimulated plant growth sufficiently to overcome or to more than overcome the handicap of lower fruit set in the several irrigated series.

Another test conducted in 1939 involved a comparison of spray (Skinner) and furrow irrigation along with a third unirrigated series. The general methods used were similar to those just described. Here again it was found that fruit set was reduced by irrigating; the average set being 20.9, 31.7, and 39.4 per cent respectively for the three series. Unlike the previous test however, the yields varied directly with the per cent fruit set, being 2.21, 3.46, and 4.10 tons per acre respectively for the spray, furrow and unirrigated series. Apparently, fruit set was most adversely affected by the spray irrigation and it should be stated that several crops were grown in each series and the tomatoes were unfavorably located in the outer part of the area covered by the Skinner line. Production in the other crops (snap beans, potatoes, peppers, and eggplant) was increased considerably by the same irrigation treatments which proved to be unfavorable to the tomato crop.

The results of these studies suggest that fruit set in tomatoes might be adversely affected by irrigating. Seemingly the tomato plant is quite sensitive in this respect to fluctuations in the soil moisture supply as might be induced by light and improperly timed irrigations. Yield increases in favor of irrigation may result at times in relation to increased plant size or total bearing area.

Studies in 1940 with tomatoes were designed similarly to those conducted with sweet corn, in which five irrigation treatments were arranged in a Latin square. Each plot measured 25 by 64 feet exclusive of guard and buffer areas and was planted with 16 plants each of five varieties. Fruit set data were secured by tagging six sets of clusters beginning with first clusters blooming May 20 and ending with those blooming on July 8. Excepting the first clusters the tagging dates coincided with irrigating dates. The plots were thoroughly irrigated by means of furrows. The season was quite agreeable and the average yield was quite high. The harvest season extended from June 21 to August 3, and data on blossom end rot and soil rot were secured in addition to yield data. The irrigation schedules for the irrigated series were developed with reference to the preharvest and harvest periods as indicated in Table II.

The analysis of the yield data indicated a highly significant F value for the irrigation treatments while the variety factor and interaction, variety X irrigation treatment, were insignificant. As indicated in Table II, the average per cent fruit set was almost constant for the various treatments indicating that the differences in yield were largely due to differences in plant growth on total bearing areas. All of the irrigated series were more productive than the unirrigated one. Irrigations applied during the pre-harvest period were more effective in increasing the yield. When the irrigations were applied during the harvest season only, the yield increase was slight and in this case insignificant. The greatest yields, however, were secured when the crop was irrigated throughout the entire season.

While it is not possible to present a complete discussion of the fruit set data secured in this study, it probably should be stated that for each set of clusters sampled (tagging dates), there were very small and insignificant differences in the per cent set for different varieties and for different irrigation treatments, but a very strong trend was found throughout the several blooming dates. Thus, the set began at about 80 per cent for the first clusters, declining regularly to about 5 per cent for the clusters entering their blooming period on July 8.

The per cent of the fruits affected with blossom end rot was high for the plots not irrigated, and it appears that the disorder was in-

TABLE II—FRUIT SET, YIELD AND FRUIT DECAY IN TOMATOES IN RELATION TO CERTAIN IRRIGATION TREATMENTS AS APPLIED TO A SPRING CROP IN 1940

Irrigation Treatments	No. Irrigations and Time of Application			Fruit Set		Total Yields (Tons Per Acre)	No. 1 Fruits		Decayed Fruits as Per Cent Total		Average Weight Per Fruit (Lbs)
	Before Harvest	During Harvest	Total	Per Cent	Average Per Cluster		Tons Per Acre	Per Cent Increase*	Blossom End	Soil Rot	
Irrigated entire season	3	4	7	41.0	2.46	15.2	9.3	24.0	1.86	4.72	0.29
Omitted first irrigation	2	4	6	43.8	2.61	14.3	9.1	21.3	2.16	4.80	0.29
Pre-harvest only	3	0	3	41.3	2 34	14.5	8.8	17.3	1.34	4.10	0.28
During harvest only	0	4	4	42.8	2.56	13.0	7.9	5.3	5.30	4.80	0.28
Not irrigated	0	0	0	41.9	2.46	12.0	7.5	—	4.60	2.88	0.26

*Per cent increase above the unirrigated plots. The three pre-harvest irrigations were made May 30, June 8 and 17. Irrigations during the harvest season were applied June 24, July 8, 15 and 24 (see Fig. 1 for 1940 rainfall data).

creased some for the plots in which irrigating was delayed until harvesting had commenced. Fruits infected with soil rots were more prevalent when the crop was irrigated and especially when the water was applied during the harvest season.

CONCLUSIONS

Yields of sweet corn and tomatoes, when grown in North Central Oklahoma, may be substantially increased by a few timely irrigations.

On the basis of data secured with sweet corn it appears that irrigations applied first at silking time and later while the ears are developing are most likely to be beneficial. The conclusion appears to be justified by reference to the distribution of the rainfall throughout the growing season for the region represented and by normal moisture requirements of the crop. Pre-silking irrigations appeared to increase the size of the plants but did not increase the yield of ears.

Tomato plants appear to be rather sensitive to variations in the soil moisture and fruit set may be adversely affected by irrigation treatments which are highly favorable to certain other vegetable crops. Light irrigations which undoubtedly caused marked variations in the surface soil moisture were especially detrimental to fruit set. In most instances increased yields induced by irrigating tomatoes were the result of increased plant size and not due to improvement in fruit set. Water applied before harvesting began appeared to be most beneficial as regards fruit production and the prevalence of fruit decay.

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Correlation Between Fresh Weight and Area of Tomato Leaves

By F. A. ROMSHE, *Oklahoma Agricultural Experiment Station, Stillwater, Okla.*

A STUDY of the correlation between leaf area and fruit production was included in a project pertaining to factors affecting the growth of greenhouse tomatoes. To measure the area of a sufficient number of leaves for an adequate sample by any method possible with equipment available seemed out of the question. The large size and general conformation of the leaves of tomatoes makes it impractical to measure the area by ordinary methods. The method used by Khanmai and Brown (1) in their study on red raspberries, wherein fresh weights of leaves were used as a measure of leaf area, offered a very rapid procedure if the same relationship exists between weight and area of tomato leaves.

To explore this possibility 60 mature leaves were taken from the lower part of tomato plants throughout the greenhouse. The plants had grown to a height of about 5 feet at the time the leaves were removed. Immediately after removing each leaf from the plant the leaflets were cut off, weighed to hundredths of grams, and blue-printed. It was necessary to remove the leaflets from the petiole to secure good prints and to avoid overlapping of leaflets. The leaf area was measured to hundredths of square inches from the blue-print with a planimeter. The leaves varied in size from 48 to 311 square inches.

The correlation coefficient found between the fresh weight of the leaflets and leaf area was .9670 ± .0041. When the measurements were rounded off to whole numbers the correlation was .9657 ± .0064. Both of these correlations are highly significant.

To determine if it was necessary to remove the leaflets for weighing or whether the same relationship existed if the entire leaf weight was used, 15 entire leaves were weighed, then the leaflets removed and weighed separately. The correlation secured between leaflet weight and the weight of petioles and leaflets together was .9701 ± .0102.

From the results secured in this study it is concluded that the fresh weights of tomato leaves grown in a greenhouse is an accurate measure of relative leaf area and could be used for comparative studies involving this factor.

The ratio of area to weight of the leaflets was 5.693:1, and for the entire leaves, 3.4158:1.

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Soil Moisture Conditions as Related to the Irrigation of Truck Crops on Mineral Soils

By John H. MacGillivray and L. D. Doneen, *University of California, Davis, Calif.*

THE amounts of fertilizer and of soil moisture available to the plant are of major importance. Certain methods for measuring available soil moisture are no more difficult than those used on fertilizers. Everyone recognizes the importance of soil moisture to the growth and fruiting of plants. With the increased interest in the subject, it seems desirable to review certain physiological and soil methods used successfully for measuring available soil moisture in its relation to the growth of truck crops and to irrigation practice. The relation of soil moisture to plants has been clearly presented by Veihmeyer and Hendrickson (14, 20), Magness (15), Esselen (6), Meyer and Anderson (16), and Gourley and Howlett (8). The references listed in this paper are selected to give a background for irrigation studies of vegetable crops.

Measurements of Available Water

Hendrickson and Veihmeyer's methods for irrigation research on deciduous orchards can be adapted to truck crops with little alteration and have greatly assisted studies on the irrigation of truck crops. A fruit tree has a permanent root system that absorbs water early in the season. Annual plants, including most of the truck crops, must develop their root systems each year in order to explore large masses of soil for plant nutrients and soil moisture. With most annual plants the water appears to be extracted in successive zones outward and downward from the plant (4, 5), the roots developing their maximum spread and depth as the plant approaches maturity.

After a rain or irrigation, the movement of water in a soil with free drainage will soon practically cease. This has been termed field capacity "F.C." (20), which in most cases agrees with the moisture equivalent "M.E." (21). The latter may be conveniently measured in the laboratory. The moisture equivalent is determined by Briggs and McLane's method (2, Fig. 1 and 2, Plate VI, page 141), with later modifications (25). Veihmeyer and Hendrickson, having reviewed the literature, presented results from which they conclude that the moisture equivalent is a measure of field capacity, with the possible exception of sandy soils (21). Their average ratio of the field capacity to the moisture equivalent of the air-dried samples is 1.06 ± 0.023. The moisture equivalent is an arbitrary method, standardized by various workers in this field. To obtain consistent and accurate results, one must adhere strictly to the procedure of the authors mentioned above (2, 25). The method is rapid, permitting a hundred or more determinations in a single day. It is used, consequently, for measuring field capacity.

In contrast to field capacity, where a physical laboratory method is used to measure the upper limit of moisture-holding capacity of a soil, the lower limit is found by growing plants and allowing them to wilt.

This condition of the soil is called the permanent wilting percentage (P.W.P). The use of wilting in the term P.W.P has been misinterpreted as applying to the plant. A plant is used to determine the moisture content of the soil, much as a thermometer is used to determine temperature or a diphenylamine is used to determine nitrates. Veihmeyer and Hendrickson have developed a practical method for a large number of determinations. The soil is usually air-dried and screened[1] through a 2-millimeter screen. Then sufficient soil is weighed out to fill a No. 2 friction-top can (307 by 409) within about ¾-inch of the top. A hole ½-inch in diameter is cut in the top of the can for the stem of the plant. For convenience, the cans are all brought up to the same weight. Seeds of the Dwarf Sunflower (*Helianthus annus*) are planted in the can. The soil is then wetted to field capacity by adding sufficient water to raise the soil moisture to the moisture equivalent, or by trial — that is, by adding small increments of water until all the soil is wet to field capacity. This latter method is usually necessary in the coarse-textured soils, as the field capacity and the moisture equivalent do not always agree for sands (21).

The sunflower plant is grown until it has developed three or four sets of leaves. This process may require one or more additional irrigations. At this stage of growth the plant is irrigated, and the space between its stem and the side of the hole is filled with cotton to prevent evaporation. The plant is then allowed to wilt, first lack of water being indicated by the drooping of the lower one or two sets of leaves. If these leaves do not revive when placed in a darkened moist chamber, the plant has reached the condition of permanent wilting. The authors realize that the leaves of a plant do not all wilt at the same time. Taylor, Blaney, and McLaughlin suggest the term ultimate wilting point (17), using it to indicate the soil-moisture content when all the leaves are wilted. Usually the apical leaves are immature and do not wilt until after the death of some of the basal leaves. In irrigation practice the primary interest is in the soil-moisture content at which permanent wilting first takes place. Carefully controlled experiments show that with a given soil, whether in cans in the laboratory or in the field, growth ceases at the first permanent wilting of the plant (7, 11, 12, 13).

When permanent wilting has occurred, the gross weight, including the plant, can, and soil, is determined. The wilted plant is cut off at the soil surface and weighed. As experience has shown, the weight of the roots is about half the weight of the top, and the roots contain about 80 per cent water. The weight of the plant and the water in the roots are subtracted from the gross weight. The entire can with soil and roots is dried in an oven at 110 degrees C, and the difference in weight is the loss of water from the soil. One can make a correction by subtracting the tare of the can plus the weight of the dry roots from the oven-dry weight. This method of drying the can with its entire contents has been found to be more accurate for determining permanent wilting percentage than the method of sampling the cans with a cork borer.

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[1] The question of screening the soil is always troublesome. Particles larger than 2 millimeters have such low water-holding capacity that they contribute little to the water relations of soils. If, on the other hand, gravel does occur in samples taken in the field, there seems to be no practical way of eliminating it, and it decidedly affects the moisture content of the soil in the field, since the determinations are made on the dried-weight basis of soils.

In the absence of rainfall during the growing season, one may also obtain the permanent wilting percentage of a soil by examining soil-moisture extraction curves and determining the point where the soil moisture does not decrease appreciably (5, 9, 10, 11, 22). Veihmeyer and Hendrickson (23) in 1928 concluded that the wilting coefficient could not be obtained by dividing the moisture equivalent by the factor 1.84, but found that the ratios ranged from 1.73 to 3.82. Since that date, the moisture equivalent and the permanent wilting percentage have been determined on other soils. Examination of some of the results, as given in Table I, will show that ratios vary from 1.21 to

TABLE I—Relation Between Soil Type and the Possible Available Water in the Soil

Soil Type	Location	M.E	P.W.P.	Ratio of M.E./P.W.P.	Lbs per Cu. Ft. Dry Soil	Inches of Available Water Per Ft. Depth	Lb of Available Water Per Cu. Ft. of Soil
Yuma sand	Arizona	4.79	3.17	1.51	85†	0.26	1.38
Oakley fine sand	California	3.29	1.33	2.47	90	0.34	1.76
Salinas fine sandy loam	California	28.23	20.05	1.41	85†	1.34	6.95
Yolo fine sandy loam	California	16.80	8.93	1.88	83	1.26	6.53
Delano sandy loam	California	9.09	4.17	2.17	85	0.80	4.18
Fresno sandy loam	California	11.09	3.08	3.60	85	1.31	6.81
Aiken clay loam	California	31.12	25.70	1.21	68	0.71	3.68
Salinas silt clay loam	California	28.33	12.49	2.26	83	2.53	13.15
Salinas clay	California	34.50	16.80	2.05	83	2.83	14.69
Yolo clay	California	27.33	12.53	2.18	83	2.36	12.28
Sandy loam	Colombia, S. America	24.50	10.71	2.28	85†	2.26	11.76
Anthony sandy loam	New Mexico	7.52	4.00	1.88	85†	0.58	2.99
Brazito fine sand	New Mexico	2.58	1.58	1.63	85†	0.16	0.85
Gila silt loam	New Mexico	17.28	8.23	2.10	85†	1.48	7.70
Gila clay	New Mexico	30.42	16.00	1.90	85†	2.36	12.26
Dunkirk silty clay loam	New York	21.70	5.02	4.35	85†	2.73	14.18
Plainfield fine sand	Ohio	2.40	1.36	1.76	85†	0.17	0.88
Brockton clay loam‡	Ohio	24.51	11.55	2.12	87	1.98	11.28
Wooster silt loam‡	Ohio	23.36	6.12	3.82	87	2.89	15.02
Catherine loam‡	Oregon	37.90	19.03	1.99	85†	3.08	16.05
Redman sandy loam	Oregon	18.79	6.61	2.85	85†	1.99	10.35
Umatilla sand‡	Oregon	6.05	3.50	1.73	85†	0.42	2.17
Not listed*	Hawaii	40.20	27.75	1.46	69	1.65	8.59

*Wadsworth, H. A. Some observations upon the wilting coefficient of Kunia soil as determined by the pineapple in the balancing system of Briggs and Shantz. *Pineapple News* 4:37-43. 1930.

†Data not available. Assumed 85 pounds per cubic foot.

‡Veihmeyer, F. J. and Hendrickson, A. H. Soil moisture at permanent wilting of plants. *Plant Phsy.* 3:355-357. 1928.

4.35. Ratio is an important point in soil-moisture methods. If the permanent wilting percentage (wilting coefficient) is found by calculation, it is very simple to show that plants wilt above or below the wilting coefficient on certain soils. Thus in Table I, on those soils with a M.E./P.W.P. ratio below 1.84, plants would wilt before reaching the calculated wilting coefficient, whereas those above 1.84 would grow below the calculated wilting coefficient.

To clarify this point, California workers (20) have used the term *permanent wilting percentage* (P.W.P.) to indicate when permanent wilting occurs. Briggs and Shantz (3) used the term *permanent wilting* to state this same condition of the plant. It is also vital to remember that the P.W.P. is a characteristic or function of the soil and is found by growing plants whose roots are well distributed. When most plants are in small containers, they can usually extract all the available water before exhibiting permanent wilting and will die unless irrigated. Judging from evidence under these conditions, plants will grow at a constant rate as long as the supply of moisture is above the P.W.P. Under field conditions with the majority of the roots in contact with soil at the P.W.P., growth may cease without wilting of the plant, because few roots extend into moist soil at lower depths. Since soils vary in the amount of available water they will hold, and since plants vary as to depth of rooting, one must determine the field capacity or the M.E. and P.W.P. for the entire depth of soil in which the particular plant grows roots. From this information one can calculate the amount of water available to a truck crop in an irrigation experiment. For the shallow-rooted crops the field capacity and P.W.P should probably be determined for every 6 inches depth, sampled; for deeper-rooted crops in foot depths; and for extremely deep-rooted crops, with uniform-textured soil, in depths of 3-foot cores. The evidence in Table II indicates considerable variations in M.E. and P.W.P. and their ratios at different depths of soil. In irrigation experiments it is desirable to determine the M.E. and P.W.P. on representative samples from each depth of soil sampled, and often the M.E. is determined on the individual soil-moisture samples from each plot and for each date sampled. This is essential in determining the available water and for obtaining smooth curves of water extraction.

All the soil listed as "Yolo sandy loam" in Table II occurred in an area covering about 15 acres. This soil, although classified as fairly uniform illustrates the wide range of soil-moisture properties in a relatively small area. On a portion of this area cantaloupes were grown. The soil samples secured from two different locations listed in Table II — namely, plot 11 and plot 8, which were located about 75 feet apart, illustrate the difference in water-holding capacity of the soil in a relatively small area. This difference is further illustrated by the experiment with tomatoes on Yolo clay loam, plots 1 and 14. Although these two plots are in the same experiment 300 feet apart, the water-holding properties of the soils from these plots are markedly different.

Briggs and Shantz (3) studied the effect of humidity and light intensity upon the wilting coefficient. They found, in carefully performed tests, that these two factors did not significantly affect the results. They also found that all plants which thoroughly distribute their root system through the soil mass wilted at approximately the same per cent moisture for a given soil.

There is also considerable evidence that all the water between the field capacity and close to the P.W.P. is readily available for use by the plants (5, 6, 10, 11, 12, 13, 15, 18, 20, 24). Since the P.W.P. is a characteristic of the soil, anyone studying this point must use plants that have uniform root distribution (1, 22).

TABLE II—THE VARIATION IN MOISTURE EQUIVALENT (M.E.) AND PERMANENT WILTING PERCENTAGE (P.W.P.) OF SOILS FOR VARIOUS DEPTHS AND THE RATIO OF $\frac{\text{M.E.}}{\text{P.W.P.}}$

Crop		Depth of Sample (Feet)											
		0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12
					Yolo Sandy Loam, Davis								
Sweet corn	M.E.	15.6	13.5	16.6	20.0	15.0	15.7	—	—	—	—	—	—
	P.W.P.	7.9	7.6	8.2	9.8	8.2	8.1	—	—	—	—	—	—
	Ratio	1.97	1.78	1.98	2.04	1.83	1.94	—	—	—	—	—	—
Watermelons	M.E.	19.6	17.2	18.1	19.4	14.8	15.8	—	—	—	—	—	—
	P.W.P.	8.1	8.5	8.7	9.3	7.9	7.6	—	—	—	—	—	—
	Ratio	2.42	2.02	2.08	2.09	1.87	2.08	—	—	—	—	—	—
Cantaloupe, plot 11	M.E.	19.6	18.2	19.0	19.6	17.6	16.2	—	—	—	—	—	—
	P.W.P.	9.5	9.5	9.8	10.0	9.0	8.6	—	—	—	—	—	—
	Ratio	2.06	1.91	1.95	1.96	1.94	1.88	—	—	—	—	—	—
Cantaloupe, plot 8	M.E.	15.8	12.9	13.1	14.4	25.1	17.3	—	—	—	—	—	—
	P.W.P.	8.1	7.4	7.5	8.5	10.2	8.8	—	—	—	—	—	—
	Ratio	1.95	1.74	1.75	1.69	2.46	1.97	—	—	—	—	—	—
					Fresno Sandy Loam, Keyes								
Watermelons	M.E.	7.7	8.6	10.5	11.5	—	—	—	—	—	—	—	—
	P.W.P.	3.7	3.8	5.2	6.2	Hardpan		—	—	—	—	—	—
	Ratio	2.08	2.26	2.02	1.85	—	—	—	—	—	—	—	—
					Yolo Clay Loam, Davis								
Tomatoes, plot 1	M.E.	25.9	28.3	27.4	27.4	21.9	18.5	18.8	20.0	19.7	20.8	17.6	19.2
	P.W.P.	11.3	11.2	10.1	9.4	10.1	8.7	8.8	9.0	9.4	8.8	9.2	9.1
	Ratio	2.29	2.53	2.74	2.96	2.17	2.13	2.14	2.22	2.09	2.36	1.94	2.11
Tomatoes, plot 14	M.E.	24.7	22.3	20.3	16.8	13.8	12.8	15.8	9.3	10.6	23.9	23.1	24.1
	P.W.P.	10.3	8.7	8.8	8.5	7.5	7.2	8.6	5.9	6.6	10.7	11.1	10.1
	Ratio	2.40	2.56	2.31	1.98	1.83	1.78	1.84	1.58	1.61	2.23	2.08	2.39

FACTORS AFFECTING THE NEED FOR IRRIGATION WATER

Under irrigated conditions there are two sources of water available to the plant: (a) the water stored in the soil from rain and (b) irrigation water. The amount available to a crop depends upon (a) the characteristics of the soil (previously discussed); (b) the spacing of the plants and the depth of the soil occupied by their roots (volume); and (c) the loss of water by direct evaporation from the soil (minor). The factors affecting water loss from plants need not be reviewed, and water loss from the soil by direct evaporation occurs almost entirely from the surface 4 to 8 inches of soil. The loss by surface evaporation is not important unless the amount of water added wets only the top few inches of the soil or unless the plant is very shallow rooted.

The depth and spread of the roots affect soil moisture fully as much as does the type of soil. When moisture is determined from soil samples taken for a uniform spacing and depth, at regular intervals, one can study the extraction of water, and consequently the root distribution (4, 9, 11, 10, 22). This method is illustrated with watermelons by Doneen, Porter, and MacGillivray (5). Most of the root-depth studies are made on the nonirrigated plots, since the wet plots usually are near field capacity and show only slight extractions between irrigations. Some of the data from these studies are found in Table III.

TABLE III—TRUCK CROP ROOT DISTRIBUTION AS REPORTED BY DIFFERENT WORKERS

Crop and Irrigation Treatment	Location	Root Extent (Inches)			Maturity Crop	Authority
		Lateral	Many Vertical	Extreme Vertical		
Carrot	Nebraska	60	48	84	Mature	Weaver, Bruner
Carrot (dry)	California	BMR	36	36	Mature	Doneen, MacGillivray
Carrot (medium)	California	BMR	36	36	Mature	Doneen, MacGillivray
Cantaloupe (dry)	California	BMR	72	72	Mature	Doneen, MacGillivray
Cantaloupe (medium)	California	BMR	72	72	Mature	Doneen, MacGillivray
Pepper	Georgia	50	24	—	Mature	Cochran
Pepper	California	BMR	48	—	Mature	Doneen, MacGillivray
Sweet corn						
Golden Bantam (dry)	California	BMR	48	60	Mature	Doneen, MacGillivray
Golden Bantam (medium)	California	BMR	48	60	Mature	Doneen, MacGillivray
Oregon Evergreen (dry)	California	BMR	48	60	Mature	Doneen, MacGillivray
Oregon Evergreen (medium)	California	BMR	48	60	Mature	Doneen, MacGillivray
Tomato	Nebraska	84	42	66	Mature	Weaver, Bruner
Tomato (dry)	California	BMR	108	144	Mature	Doneen, Jones
Tomato (medium)	California	BMR	108	144	Mature	Doneen, Jones
Watermelon						
Watermelon (dry)	California	BMR	72	—	Mature	Doneen, Porter, MacGillivray
Watermelon (medium)	California	BMR	72	—	Mature	Doneen, Porter, MacGillivray

BMR = Beyond middle of row; Dry = little or no irrigation, Medium = sufficient irrigation for maximum growth.

Evidently, various species of vegetables root to different depths. The volume of soil occupied by the root system greatly affects the total amount of water available to the plant. If Oakley fine sand at field capacity is planted to Golden Bantam corn spaced 36 by 16 inches and rooting 36 inches deep, the plants have 1 acre-inch of available water. In Yolo fine sandy loam, on the other hand, they have 3.6 acre-inches; and in a Salinas clay, 8.5 acre-inches (calculated from Table I). If tomatoes are planted on these same soils spaced 6 by 6 feet and root 9 feet deep, the Oakley fine sand would have 3.1 acre-inches, Yolo fine sandy loam 11.3 acre-inches, and Salinas clay 22.5 acre-inches (Table I). The experiment listed in Table II with tomatoes (plots 1 and 14) may be used to illustrate the quantity of water available to the crop between individual plots. Plot 1 would have 18.7 acre-inches of available water in the surface 9 feet of soil, whereas for the same depth plot 14 would have only 11.6 acre-inches. "Acre-inch" indicates water to a depth of 1 inch over an acre or to a depth of 1 inch over any surface.

BASIS FOR IRRIGATION RECOMMENDATIONS

The purpose of irrigation research is to determine a scientific basis for irrigation as well as to aid the farmer in producing truck crops with greatest economy. The determination of crop yields under different irrigation treatments, together with a study of soil moisture, does give an accurate basis for irrigation. Since these studies were made primarily in a single area, one should not apply them in other areas without considering the water-holding capacity of the soil and the climatic conditions. In an irrigation program, however, one may follow certain basic principles, some of which have been discussed in this article. With crops studied at Davis, for example, watermelons — a total of 7 to 8 acre-inches has been needed to produce a maximum crop on Yolo sandy loam (7).

As has been shown repeatedly, when a plant reduces the soil moisture to the P.W.P. there is a retardation of growth. Thus, if soil moisture is the only limiting factor, a few systematic measurements of fruit or vegetative growth will indicate the approximate time in which the plant has exhausted the soil of readily available moisture. After keeping such records for a few years one can time the irrigations so as to prevent wilting or slowing of growth and reduce the number of measurements.

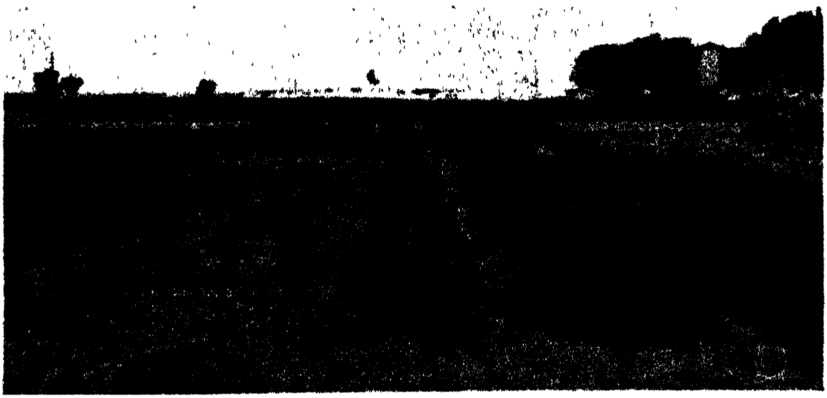

FIG. 1. Unirrigated (dry-A) and amply irrigated (wet-B) plots of Imperator carrots at Davis in 1940. The dry plot shows small size of plants, but no wilting.

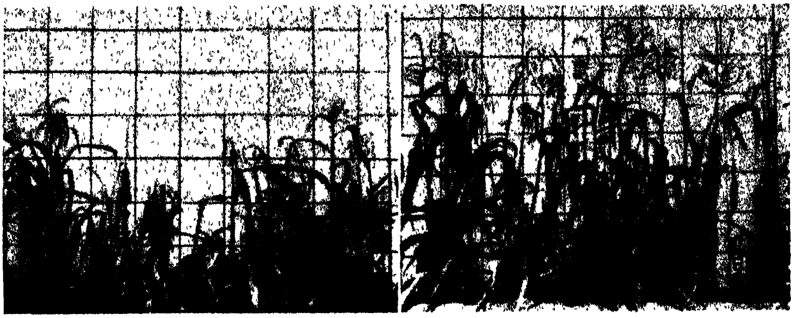

FIG. 2. Unirrigated (dry-A) and amply irrigated (wet-B) plots of Golden Bantam sweet corn grown at Davis, 1941. Sweet corn shows temporary wilting under field conditions, but death from permanent wilting is uncommon because the plants will remain alive with the majority of the roots at the permanent wilting percentage.

Some growers use the appearance of the soil sample as a criterion for need of irrigation. Experience has indicated that it may be hazardous to judge the available moisture in a soil by either color or texture. With some particular types, however, a rough estimate of the available water may be made, but this requires experience and should be supplemented in the beginning with data on soil-moisture studies.

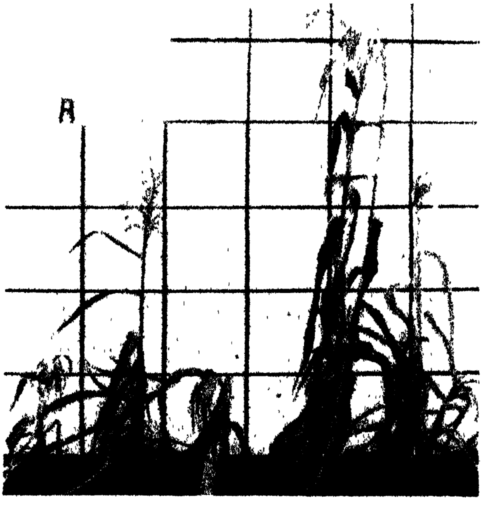

FIG. 3. Unirrigated (dry-A) plot of Golden Bantam sweet corn at Davis, 1940. Seed planted at same date did not germinate uniformly and the first germinating seed produced plants which extracted most of the moisture. Later germinating seeds were stunted.

The leaves of plants do not always droop or wilt when the soil is exhausted of readily available moisture in the major part of the root zone under field conditions. Some plants behave in this way when grown in the greenhouse in a limited volume of soil. Among the crops that do not show typical wilting in the field are tomatoes, onions, carrots, watermelons, cantaloupes, peppers, pumpkins, and asparagus. Some plants may change slightly in color when the soil is exhausted of readily available moisture. This condition usually occurs, however, after growth has been checked; and it is hard to detect unless a comparison is

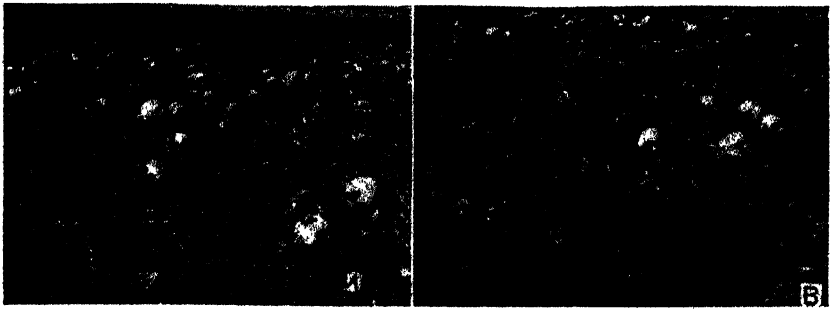

FIG. 4. Unirrigated (dry-A) and amply irrigated (wet-B) plots of Connecticut field pumpkin at Davis, 1941. The dry plot produced 22½ tons and the wet plot 28½ tons per acre. The dry plot has slightly less foliage, but there was no sign of wilting.

made with an adjacent plot that has not suffered from a shortage of water. Even in small cans, it is difficult to obtain typical wilting with onions. Onions grown late in winter in gallon containers in the greenhouse were left for 5 months through the summer without water. In the fall over half the plants were alive, with green stalks, and others were dormant. In the field, sweet corn and beets are more liable to temporary wilting than many other crops. This wilting at first occurs only during the middle of the day, or under conditions of extremely high transpiration; a few roots usually extend to the deeper soil, which has not reached the permanent wilting percentage.

CURRENT SOIL-MOISTURE RESEARCH ON TRUCK CROPS

Reports from two stations in the corn belt studied the effect of irrigation on the yield of lima beans. One obtained a 25 per cent increase from irrigation, and the other no significant increase in yield. Unless these data are related to readily available water of the soil, to rainfall, and to climatic conditions, the results of these two experiments have little value for a grower who wants to know when and how much to irrigate. In the East many consider an acre-inch a suitable irrigation application, whereas in the West we apply from several inches up to 8 to 12 inches, depending upon the depth of rooting of the crop and upon the amount of moisture removed from the soil. In this connection, Table I is of interest because calculations can be made that an inch of water applied to the Oakley fine sand would fill the soil with available water to a depth of 3 feet, whereas on Salinas clay it would wet the top 4 inches. In the first soil it would be a fair irrigation; but in the second soil little water would be obtained by the roots, and most of it would be lost by surface evaporation. When irrigation experiments are made without measurement of available soil moisture, they are valid only for that particular area of soil; difficulties may be encountered if they are applied to another area even with the same type of soil. A review of the truck-crop papers published in the last 10 years indicate that most workers neglect the soil-moisture phase of the work. In this group of 20 papers, only three in any way measured the available water in the soil.

SUMMARY

This article has brought together the soil-moisture methods used in an irrigated area which will be of interest from the standpoint of future reports of the California Station on the irrigation of truck crops.

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Influence of Photoperiod on the Time of Flower Primordia Differentiation in the Perfection Pimiento (Capsicum frutescens L)

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WITHIN the past 20 years many horticultural plants have been classified as either long-day or short-day, according to the photoperiod under which they bloom. Auchter and Harley (2) working with the effects of day lengths on the behavior of several Horticultural crop plants in 1924 reported results, which show the pepper (*Capsicum frutescens L.*) to bloom earlier under short than under long-day conditions. Deats (7) also found that moderately short-day conditions were conducive to early flowering. More recently Cochran (4, 5) has confirmed these results and classified the pepper as a short-day plant. As far as the author is aware, however, no previous work has been done with this crop to determine whether the photoperiods found necessary for earliest blooming are also essential for the earliest differentiation of flower primordia.

Materials and Methods

Forty-eight 6-inch clay pots were filled with a highly fertile greenhouse potting soil on September 17, 1941 and placed in a steam soil sterilizer where they remained for 6 hours at 20 pounds pressure. After the soil in the pots had been allowed to thoroughly cool, 100 seed of an improved strain of Perfection pimiento were sown in each pot and covered ½ inch deep. All pots were watered and left side by side on the greenhouse bench for 72 hours. The various treatments were set up on September 20, 7 days before any of the seedlings broke through the surface of the soil. Each treatment consisted of six pots. These were placed in a flat and packed with peat moss to prevent the soil from drying out after which the light treatments 0, 6, 8, 10, 14, 18, 24 and normal day, about 12 hours, were begun. The 0-hour treatment was left in a small dark chamber; all other lots were moved into the greenhouse each morning at 7 o'clock from a large dark chamber and left exposed to the daylight for the required number of hours. The dark chambers were made of 2x2 inch dressed pine lumber and covered with doubled black sateen cloth to exclude the light.

The supplementary light was supplied by 100 watt Mazda lamps suspended 16 inches above the plants. The temperature of the greenhouse was maintained in the vicinity of 70 degrees F except on bright sunny days when it ran up higher even with the ventilators open. No special arrangements were used to control humidity; however, by watering the earth floor and sand in the benches it was maintained moderately high. Temperature differences between the inside and outside of the dark chambers were apparently not great enough to have had much effect on the development of the plants.

Samples of plants were taken at weekly intervals for the first 3 weeks and then at 2-day intervals thereafter. At the outset freehand sections were made of the meristematic portions of the plants and examined under a wide-field dissecting microscope for flower primordia. Although this mehtod made possible the rapid examination of a large number of plants, and where the differentiation of flower parts was well under way they could be noted, the magnification (15 to 20 times) was not sufficient or the sections clear enough to detect the primordia at the time of their differentiation. In order to estabish this point samples were taken which contained a small portion of the upper part of the stem and all of the primordal meristem. At least 10 plants were sampled at a time under each photoperiod treatment. The material was killed and fixed in Karpechenko's chromacetic solution, dehydrated in alcohol, and embedded in paraffin using xylol. Longitudinal sections were cut 8 to 10 µ thick, mounted on slides, stained with Heidenhain's iron-alum haematoxylin, destained in iron-alum, rinsed in water, mounted temporarily, and observed immediately after mounting.

Experimental Results

Parts of the flower of capsicum are differentiated in the order of sepals, petals, stamens, and carpels (6). In this paper the "time of differentiation" refers to the appearance of the first whorl of the floral organs which arise on the periphery of the flattened meristematic protuberance.

Data obtained in these studies are presented in Table I.

Although there was some difference in the time of flower primordia differentiation they were formed in plants under all treatments except the 0- and 6-hour day lengths. Of the 542 seedlings that came up under the 0-hour photoperiod all became etiolated and very spindling. They failed to develop past the cotyledonary stage and by the end of the experiment all except four had died. It is common among plants however, for flower primordia to fail to differentiate in total darkness. Flower primordia have been reported in some plants when stored in total darkness, but as far as could be found, all cases have been with those types which had a large reserve of food in storage organs upon which to draw. Blaauw (3), as reported by Jones and Borthwick (10), showed this condition to exist in *Hyacinthus orientalis*, Jones and Boswell (9) and Thompson and Smith (12) in the onion, Mulder and

TABLE I—Effect of Length of Day on the Time of Flower Primordia Differentiation and on the Appearance of the First Visible Buds

Photoperiod Treatment (Hours)	Days After Seedling Emergence Until	
	Flower Primordia Differentiation	First Visible Buds Appeared
0	—	—
6	—	—
8	26	39
10	26	39
14	27	30
18	28	41
24	31	43
Normal day 12	23	35

Luyten (11) in the tulip, and Jones and Borthwick (10) in the Irish potato.

Under the conditions of this experiment floral primordia differentiated in plants subjected to the normal day, or 12-hour treatment, in 23 days after seeding emergence or 3 days ahead of that of any other photoperiod. Under both the 8- and 10-hour day differentiation took place in 26 days. As the photoperiod was increased, however, there was a corresponding increase in the time for differentiation, namely, 27 days under the 14-hour day, 28 days under 18-hour day, and 31 days under the 24-hour day. These results are in close agreement with those reported earlier by Auchter and Harley (2).

Flower primordia were not differentiated under the 6-hour photoperiod. The plants made little growth and became quite pale in color in comparison with those subjected to longer day lengths. Deats (7) reported no flower formation in pepper plants under a day length of 6½ hours; however, Auchter and Harley (2) reported the formation of both buds and flowers in this crop when grown under a 7-hour photoperiod. Although no definite experiment was set up in this work to determine the minimum photoperiod for flower primordia differentiation in capsicum it would appear from the present and above mentioned data that a day length of 7 hours is about the lower limit.

Soon after the seed were planted and before any seedlings emerged the question arose as to whether the apearance of buds is a dependable criterion of the time of flower primordia differentiation. Daily examinations were made of the plants for buds under each photoperiod after their respective dates of primordia differentiation had been determined. These findings are listed in column 2 of Table I. The time of appearance of the first visible buds under the various light treatments, with but one exception, took place in the same order as did that of floral primordia differentiation. The time from differentiation to visible buds was practically constant — 12 or 13 days.

Growth and Appearance of the Plants

The growth that the plants had attained at the time of primordia differentiation, as measured by height and green weight, Table II, varied to a considerable extent under the different lengths of day. It is to be seen from the data however, as well as from Fig. 1 that the smallest plants were produced under the shortest photoperiod, while

TABLE II—Relation of Photoperiod to the Average Height and Green Weight of Plants at the Time of Flower Primordia Differentiation

Photoperiod Treatment (Hours)	Average Height of Plants (Centimeters)	Average Green Weight of Plants (Grams)
0	—	—
6	—	—
8	7.5	0.4
10	10.5	0.5
14	12.3	0.7
18	13.0	1.0
24	15.5	1.3
Normal day 12	11.0	0.7

the largest ones were produced under the longest (24 hours) photoperiod. Therefore, in this experiment growth is shown to vary directly with the length of day, which is in accordance with the results of Garner and Allard (8), Adams (1), and Deats (7). In general the leaves and stems of plants were larger under the 14-, 18- and 24-hour day lengths than were those exposed to the 8-, 10-, and 12-hour photoperiod treatments.

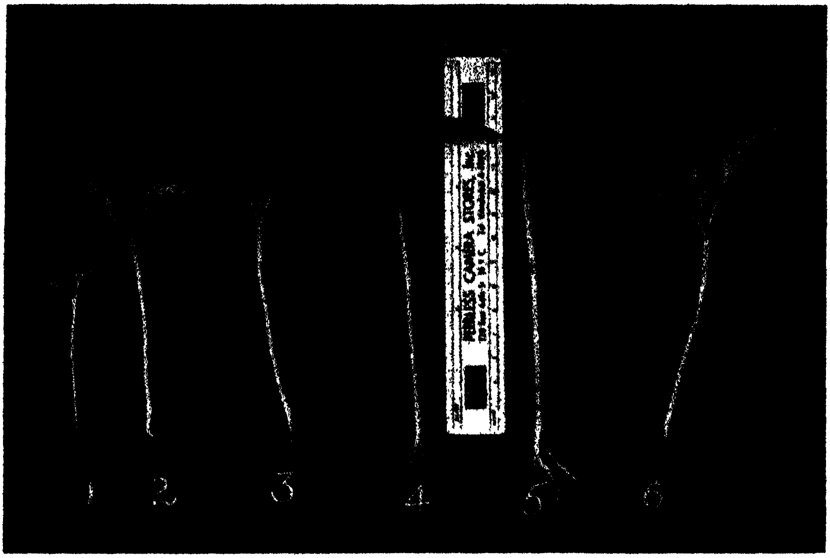

FIG. 1. Showing the stage of development of pimiento plants under the various photoperiods at which flower primordia differentiation took place. From left to right — 1, 8-hour day; 2, 10-hour day; 3, 14-hour day; 4, 18-hour day; 5, 24-hour day; and 6, normal day, 12 hours. (Photograph by Dr. L. C. Olson.)

SUMMARY

The time of flower primordia differentiation was definitely influenced by the photoperiod under which the plants were grown. No differentiation occurred in plants under the 0- or 6-hour day lengths; however, it did take place under the 8-, 10-, 14-, 18-, 24-, and normal day (12-hour) photoperiods. Differentiation was found to have taken place first in the normal-day plants, 23 days after they had emerged from the soil. It took place in 26 days under both the 8- and 10-hour treatments, in 27 days under the 14-hour day, in 28 days under the 18-hour day, and in 31 days, under the 24-hour or continuous daylight treatment.

With but one exception the time of appearance of the first visible buds occurred in the same order under the various photoperiods as the primordia were differentiated.

Growth of the plants at the time of primordia differentiation, as measured by height and green weight, varied directly with the photoperiod under which they were grown.

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Depth-of-Planting Studies with Asparagus in California

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DEPTH-OF-PLANTING studies with asparagus have been conducted by the California Agricultural Experiment Station in two different locations: at Davis from 1924 to 1936, and on Ryer Island from 1930 to 1939. The growing conditions and methods of handling the crop varied considerably between the two locations.

At Davis the soil is a deep Yolo silt loam. The variety used was Palmetto. Plots were in duplicate. The crowns were set in the permanent plots in the winter of 1923–24. They were spaced 2 feet apart in the row; the rows were 7.5 feet apart and 236.5 feet long. Two depths of planting were used, 8 and 12 inches. The first cutting was made in 1925. As the plots were cut for only a short time in 1925, the data for that year were not included in the analyses. The date of first cutting each year varied somewhat with climatic conditions, but it was usually in late February or early March. The last cutting for the season in 1926 was April 25; in 1927 and 1928, May 15; in 1929, 1930, and 1931, May 20; in 1932, May 28; in 1933, May 24; in 1934, May 10; and in 1935 and 1936, May 20. All spears were cut green throughout the season and were trimmed to a length of 8.5 inches.

The plantings on Ryer Island were on a peat-sediment soil. These plots were located in a portion of a commercial planting and received the same cultivations, irrigations, and harvesting practice as the commercial field. Mary Washington crowns were set in the winter of 1930; rows were spaced 7.5 feet apart, and crowns were set 2 feet apart in rows 250 feet long. The depth of planting used were 4 to 5, 7 to 8, and 11 to 12 inches. Five replicates were planted. The plots were cut for the first time in 1932 and then only for a period of 4 weeks during the shipping season. In 1933 they were cut until May 15, but in subsequent years harvesting continued until the end of the canning season, which varied from year to year between June 1 and 30. During the shipping season only those spears were cut that were 7 inches or more above the soil surface. The spears were cut about 2 inches below the surface and were trimmed to 9 inches in length. During the canning season high ridges were made over the rows, and the spears were cut 9 to 10 inches below the surface and trimmed to a 7-inch length. Yield and weight records of Ryer Island plots are based upon these trimmed lengths of 9 and 7 inches.

RESULTS

The results secured at Davis are presented in Table I. In all comparisons at Davis there were only two depths of planting and two replicates, which gave only one degree of freedom for treatment and one for error. This makes necessary a very large F value for the test to be statistically significant. The mean weight of spear was heavier every year at the deeper planting, but the differences were not sufficiently large for significance. More spears were harvested per crown

TABLE I—COMPARISON OF THE PERFORMANCE OF ASPARAGUS PLANTS SET 8 AND 12 INCHES DEEP (1926–36, DAVIS, CALIFORNIA)

Depth of Planting (Inches)	Mean Weight of Spear (Grams)	Spears Harvested Per Crown		Mean Annual Yield Per Acre (Pounds)	Percentage of Spears Harvested to April 1	
		Number	Weight (Grams)		By Count (Per Cent)	By Weight (Per Cent)
8	24.6	41.8	1,001	6,394	17.64	19.28
12	28.3	30.3	821	5,242	15.17	15.95
L.S.D.	Not significant	Not significant	181*	1,014*	Not significant	Not significant

*Difference required for significance at the 5 per cent level.

from the shallow planting. Every comparison for the 11 years was in favor of the shallow plantings, but the difference was not statistically significant. The weight of spears harvested per plant and per acre was always heavier at the shallower planting.

A comparison of earliness was made by calculating the percentage of the crop harvested by April 1. The amount harvested before April 1 varied considerably from year to year, due mostly to environmental conditions. However, the shallower planted crowns seemed to have a slight advantage in both the number and weight of early spears produced. But, in spite of the fact that the shallower planted crowns produced more spears and a greater weight of spears, the difference was not sufficiently large to be significant.

The results of the tests on Ryer Island are summarized in Table II. There were no significant differences between depths of planting in mean weight of spear, number of spears harvested per crown, yield per acre, and percentage of the crop harvested by April 1. The mean weight per spear was heavier on the 11 to 12 inch than on the 4 to 5 inch every year except in 1939. The 7 to 8 inch planting had a higher mean weight per spear than the 4 to 5 inch planting every year except 1937 to 1939. None of these differences are significant, however. There was no trend of differences between any of the plots for earlier production.

TABLE II—COMPARISON OF THE PERFORMANCE OF ASPARAGUS PLANTS SET AT THREE DIFFERENT DEPTHS (MEANS FOR 8 YEARS, 1932–39, RYER ISLAND, CALIFORNIA)

Depth of Planting (Inches)	Mean Weight Per Spear (Grams)	Number of Spears Harvested Per Crown	Yield Per Acre (Pounds)	Percentage of Spears Harvested to April 1	
				By Count (Per Cent)	By Weight (Per Cent)
4 to 5	34.2	14.2	3,178	14.22	18.44
7 to 8	35.0	15.0	3,232	14.54	18.66
11 to 12	35.7	14.7	3,237	14.14	18.47

DISCUSSION

The results obtained at Davis and on Ryer Island are not comparable as the soils are entirely different. The peat-sediment soil on Ryer Island dries quickly, warms up more readily, and production starts earlier in the spring than on the heavier soil at Davis. It has been a common observation at Davis in a year-old nursery where the crowns are about 2 inches deep that growth starts much earlier in the spring than in an established planting where the crowns are deeper below the soil surface. On Ryer Island the difference in the time of appearance of spears in the nursery and in older plants is small. In view of this, it is probable that the tendency for earlier production at Davis with shallow planting has a real significance, although the analyses do not show a statistically significant difference due to the high F value required with one degree of freedom.

The data reveal that from the standpoint of total yield there is no advantage gained by deep planting on Ryer Island or at Davis, but that there was a decrease in yield due to deep planting on the heavier soil at Davis. There was a trend for larger spears both at Davis and on Ryer Island with deeper planting. It is probable that in a more critical test the differences at Davis would have been significant.

The Influence of Storage Conditions Upon the Germination of Onion Seed

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ONION seed loses its viability in a relatively short time when stored in common storage in the South. Seed may produce good stands when planted in the spring, but fail to germinate entirely when planted the following fall. This uncertainty of germination is a matter of concern to growers and seedsmen alike.

Beattie and Boswell (1) stored seed of four different varieties of onions, some sealed and others unsealed under conditions that varied with respect to temperature and moisture content of seed. Germination tests of seed representing different treatments were made over a period of 7 years. Results showed among other things that: (a) onion seed stored in sealed containers remain viable longer than when stored in non-sealed containers; (b) those with a low moisture content remain viable longer than those stored with a high moisture content; and (c) that seed remains viable longer at a low temperature than at a relatively high temperature.

The tests herein reported were begun in the spring of 1937. The variety used was Yellow Bermuda. Seed was grown at the Texas Agricultural Experiment Substation No. 16 at Iowa Park, Texas, and was of the 1936 crop. From the time the seed was harvested in 1936 until the spring of 1937, it was stored in a field laboratory at the substation headquarters. In March of 1937, a germination test was made, and 93.6 per cent of the seed germinated and produced seedling plants. The seed stock was then subdivided into a number of samples of 8 grams each, and were placed in (a) cloth bags, (b) moisture-proof cellophane bags, (c) pint glass jars, which were sealed immediately, and (d) in pint glass jars, which were sealed immediately under vacuum equivalent to 15 inches of mercury. The cellophane bags were sealed by folding the top down several times and placing a rubber band tightly about them. Separate samples were prepared in each type of container so that tests for viability could be made over a number of years. They were then divided equally into a *common storage* series, and a *cold storage* series.

Samples in the common storage series were stored in a cabinet in the work room of a greenhouse at College Station, Texas. The temperature extremes varied from about 40 degrees F in the winter to 90 and 95 degrees F during the summer months. Samples in the cold storage series were stored where the temperature ranged from 34 to 40 degrees F. Germination tests were made of seed taken from the four types of containers of each series during the spring and fall of each year, except in 1940 and 1941, when only one test was made each year.

The tests were made by planting 500 seeds from each sample in flats of sand, 100 seeds in each of five rows. Tests in the fall of 1937 were made in sand which had not been sterilized. Considerable loss was caused by damping-off. Beginning in the spring of 1938 all tests were made in sterilized sand, and the results obtained represent more accurately the true viability of the seed than the earlier tests.

TABLE I—A COMPARISON OF THE VIABILITY AT SUCCESSIVE PERIODS OF ONION SEED STORED IN DIFFERENT CONTAINERS IN COLD AND IN COMMON STORAGE

Date of Germination Test	Interval From Maturity of Seed Until Germination Test (Months)	Storage Container							
		Cloth Bag		Cellophane		Sealed in Glass		Sealed in Glass Under Vacuum	
		Common Storage (Per Cent)	Cold Storage (Per Cent)	Common Storage (Per Cent)	Cold Storage (Per Cent)	Common Storage (Per Cent)	Cold Storage (Per Cent)	Common Storage (Per Cent)	Cold Storage (Per Cent)
Fall 1937*	15	38.2	61.4	22	58.4	35.8	63.8	35.2	40.6
Spring 1938	20	71.2	96.2	28.2	96.2	93.2	90.8	95.8	93
Fall 1938	27	0	78.6	0	74.8	88.2	90	89.2	91
Spring 1939	32	0	86.6	0	86.2	93.4	93.2	94.2	91.4
Fall 1939	39	0	68.8	0	54 2	62.0	86.4	77.0	90.6
Spring 1940	44	0	72.4	0	62.2	70.4	93	85.2	95
Fall 1941	62	0	17.8	0	3.2	—	—	—	—

*Low germination percentage indicated is probably due to loss from damping off.

The results of all germination tests are summarized in Table I.

Seventy-one per cent of the seed stored in cloth bags germinated after 20 months in common storage, but none germinated in tests conducted after 27 months. The seed ceased to be viable between the 20th and 27th month since none germinated in the tests during the 27th month or any of the tests conducted afterwards. By contrast seed stored in cloth bags and kept in cold storage germinated fairly well (72.4 per cent) after 44 months, but only poorly (17.8 per cent) after 62 months.

Results of germination tests of seed stored in cellophane bags closely parallel those for seed stored in cloth, for both common and cold storage. None germinated after 27 months in common storage; 62 per cent germinated after 44 months in cold storage, but only 3.2 per cent germinated after 62 months.

Onion seed sealed in glass jars was viable when tested after having been stored for 44 months. There was little difference in the percentage of germination of that in cold and in common storage for the first 32 months. After that the seed held in cold storage germinated better than that held in common storage. A good percentage of the seed that was sealed was viable when tested after 44 months in common storage; whereas that stored in cloth bags in common storage ceased to be viable between the 20th and 27th month. For the samples kept in cold storage there was little difference in the germination of seed sealed in glass and that in cloth bags for the earlier tests; the sealed samples, however, germinated better when tested during the 39th and 44th months. Of the samples kept in cold storage there is little difference in the results for seed sealed in glass and that sealed in glass under vacuum; both germinated well throughout the duration of this experiment. Of the seed kept in common storage there is little difference for the first 32 months; after which the data show that the lot which had been sealed under vacuum had a slightly higher germination percentage.

Observations on vigor of seedlings were made in the spring of 1940; the seedlings were from seed which had been in storage 44 months. There were evident differences in the seedlings representing the several different lots of seed. Those seedlings from the two lots of seed which were kept in cold storage, sealed and sealed under vacuum, were the largest and most vigorous in appearance. The seed which was sealed, and that sealed under vacuum, and held in common storage, as well as that stored in cloth and in cellophane in cold storage produced seedlings which were comparatively weak and spindling giving evidence of lowered vitality.

These results are in close agreement with those of Beattie and Boswell with respect to the influence of temperature upon viability, and also with respect to the influence of sealing upon longevity. They further suggest the value of sealing under vacuum for onion seed stocks that are to be kept for long periods of time in common storage.

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A Chemical Test for Pungency in Peppers[1]

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PLANT breeders and seed growers who work with hot peppers often encounter difficulty in determining the pungency of lines and individual plant selections. Insofar as the writers are aware, only organoleptic methods have been employed. Direct tasting of fruit has proved unsatisfactory because the taste is quickly "destroyed", and non-pungent fruits cannot then be identified. Attempts to determine pungency by tasting diluted fruit extracts have proved unsatisfactory.

At the suggestion of a seedsman faced with the problem of maintaining stock seed of hot pepper varieties, the writers made a search of the literature to learn if any chemical test was known for the determination of capsaicin, the active constituent of pepper fruits. Fodor (1) observed that capsaicin reacts with vanadium salts, and vanadium oxytrichloride was found to be the most satisfactory. A series of color changes were involved varying from a light greenish yellow to dark meadow green as the capsaicin content increased. Tice (2) used the method with certain modifications in assaying capsicum powder.

As a result of preliminary experiments, certain simplifications were made in the procedure of Fodor and Tice which would permit its rapid application in testing individual plant selections. The test was applied to a number of plants of several different varieties of peppers for the purpose of observing variations in capsaicin content both within and between varieties.

SAMPLING

Tests of fruit from the same plant at different stages of development indicated that in the hot varieties, capsaicin content was high in mature green and ripe fruits. For the sake of uniformity and because the colorimetric reaction is somewhat masked by the presence of chlorophyll, only ripe fruits were used. Tests of several ripe fruits all harvested from the same plant at one time indicated that only minor variations occurred between them. For the purpose of distinguishing "hot" from "sweet" individual plants, single fruit samples are considered sufficient.

The seeds and pericarp of hot peppers contain but little capsaicin while its concentration is high in the placenta and in the interlocular septae. The entire fruit may be used for the capsaicin test; but for the purpose of breeding work, it appears desirable to remove the seeds so they will be available for further planting. The balance of the fruit is dried in an oven at 130 to 150 degrees F and each sample is ground separately in a mortar. It is essential to have the fruit very dry at the time of grinding as well as the ground powder when the test is run. Storage in a desiccator or a short period of redrying in an oven is desirable in case the dried fruits are not to be ground immediately.

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[1] Journal Article No. 569 (n. s.) from the Michigan Agricultural Experiment Station.

The ground powder may be handled in the same manner or may be placed in tightly stoppered bottles.

The placenta and interlocular septae are more readily ground than the pericarp. Thus, finer particles contain a larger proportion of capsaicin, and care should be taken in selecting samples not to get a preponderance of either fine powder or coarse particles.

THE INDICATOR

The indicator used is a 1 per cent solution of vanadium oxytrichloride in carbon tetrachloride. Because water reacts with the vanadium compound and desensitizes the color reaction, great care must be used in preparing the indicator. It is well to dry all apparatus used in an oven, and the carbon tetrachloride may be dried by the addition of calcium chloride and filtering.

The indicator is relatively unstable and it is undoubtedly best to make it up fresh each day it is used. It was found convenient to remove the vanadium oxytrichloride from the sealed vial in which it comes by means of a 1 milliliter graduated pipette. The chemical can then be delivered into a dropper bottle containing the necessary volume of carbon tetrachloride. The vial of vanadium oxytrichloride should be resealed with a soft piece of paraffin and kept in a desiccator.

THE TEST

It was found to be reasonably accurate to use a measured volume of the ground powder rather than a weighed sample. A level ¼ teaspoonful is placed in a small bottle to which is added 10 milliliters of diethyl ether. The bottle is then stoppered and after shaking a few times allowed to stand for about 5 minutes. Tests indicated that no additional capsaicin was extracted by allowing it to stand for a longer period. About 5 milliliters of the extract is then decanted into a dry test tube and the indicator added from a dropper until no further color change takes place.

The extracts of ripe peppers vary from yellow through various shades of orange depending on the amount of red pigment present in the ground sample. The first few drops of the indicator apparently destroy the red pigment regardless of the capsaicin content; sweet red-pepper extracts change from an orange-red to yellow. The red pigment also disappears in hot pepper extracts, but in addition a green color develops, the intensity of which increases with the amount of capsaicin present. The green color is unstable and soon begins to fade. The color reaction of four representative varieties is illustrated in Fig. 1.

THE COLOR STANDARD

Because of the instability of the green color, it appeared desirable to have some color standard for comparison. Test tubes containing an aqueous solution of napthol yellow and varying amounts of malachite green were found to be satisfactory for this purpose even though the quality of color was not identical with that of the tests. They may be prepared in the following manner: Add 1 gram of napthol yellow to

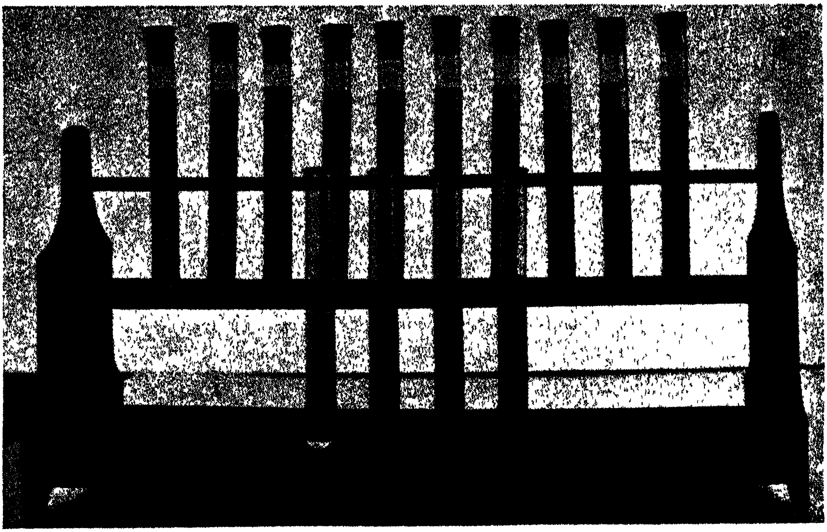

FIG. 1. Back row, color standards. Front row, left to right: Oakview Wonder (1), Long Red Cayenne (4), Red Chili (6), and Argentine Wonder (8).

250 milliliters of water and allow to stand for several hours with occasional shaking. This dye is not readily soluble, but a sufficiently yellow solution will be obtained and the undissolved portions can be removed by decanting or filtering.

A stock green solution is prepared by adding 10 milligrams of malachite green to 50 milliliters of the napthol yellow solution. A series of 10 test tubes is then prepared. Number 10 contains the stock green solution, No. 9 contains 50 per cent stock green and 50 per cent napthol yellow, No. 8 contains 50 per cent of No. 9 solution and 50 per cent napthol yellow, and so on through No. 2. Thus, each tube has half the concentration of malachite green of the next highest, except No. 1 which is straight napthol yellow. The ten color standards are shown in Fig. 1.

TEST OF VARIETIES

Fruit from a 12-plant row of the variety, Hot Portugal, were used in the development of the procedure. Tests indicated that one of the plants was non-pungent and this observation was confirmed by tasting. All the others showed a positive test but varied in the intensity of green. Those showing the lightest green color were sufficiently hot when tasted to cause a severe burning of the lips and tongue. The others were not tasted.

After the color standards were prepared, tests were made of 10 plants each of 10 varieties obtained from the trial grounds of the Ferry-Morse Seed Company at Rochester, Michigan. The color reactions observed are recorded in Table I.

It will be noted that Oakview Wonder, a sweet variety, was the only one among those tested that did not show some variation while

TABLE I—DEGREE OF PUNGENCY OF TEN PLANTS EACH OF NINE PEPPER VARIETIES AS INDICATED BY VANADIUM OXYTRICHLORIDE TEST

Variety	Plant Number										Seedman's Description
	1	2	3	4	5	6	7	8	9	10	
Long Red Cayenne	3	4	3	4	3	4	4	3	4	3	Hot
Red Chili	5	6	6	6	6	5	6	4	5	6	Hot
Argentine Wonder	8	8	9	8	9	8	8	8	8	8	Hot
Floral Gem	4	3	4	3	5	4	5	4	3	3	Hot
Hungarian Yellow Wax	2	2	3	2	3	2	1	3	3	1	Hot
Anaheim Chili	3	3	2	3	3	3	3	3	2	3	Mildly pungent
Bulgarian White	2	2	2	2	1	2	2	2	2	1	——
Sweet Roumanian	1	1	1	1	3	1	1	1	1	1	Sweet
Oakview Wonder	1	1	1	1	1	1	1	1	1	1	Sweet

Sweet Roumanian showed no reaction with the exception of plant 5. Tasting indicated that this plant was the only one among the two sweet varieties that showed any degree of pungency. Hungarian Yellow Wax is classified as a hot variety although some seedsmen list a sweet strain. According to the test, two plants were sweet and the others mildly pungent. These observations were verified by tasting.

It is interesting to note the variations in the colorimetric reactions observed between varieties otherwise merely classified as hot. Limited organoleptic tests did not reveal differences between Long Red Cayenne, Mexican Chili, Red Chili, Floral Gem, and Argentine Wonder. Apparently the mucous membranes of most persons are so highly sensitive to capsaicin that variations in concentration above a certain point cannot be distinguished. On tasting samples given a No. 1 colorimetric reading, no pungency was detected. Those classified as No. 2 had little effect on the tip of the tongue but the presence of capsaicin was detected if the powder was swallowed. No doubt a pepper giving a No. 2 reading would pass as a fairly sweet pepper. Samples which gave a No. 3 reading were definitely pungent but not as intensively so as those showing a higher colorimetric reaction. Samples classified as No. 4 were definitely hot and indistinguishable from those of a higher reading.

DISCUSSION

In spite of the fact that this test for pungency requires drying of the fruit, thus eliminating the possibility of applying it in the field, it would appear to be of value to the pepper breeder, particularly when working with pungent varieties. The variety tests indicate very clearly that occasional sweet plants occur in otherwise hot varieties. These would be difficult for a seedsman to identify if tasting was the only method available. No doubt some of the less pronounced variations in colorimetric readings are due to hereditary variations in pungency, which could be more readily eliminated with the aid of this test.

Insofar as the writers are aware, no serious attempt has been made to classify pepper varieties according to their degree of pungency. That variations among the hot pepper varieties do exist is clearly indicated by the differences obtained in the limited variety tests conducted. The color standards described above might be used in making such a classification.

SUMMARY

A chemical test for the determination of the degree of pungency in peppers is described. A sample of the dried and ground fruit is treated with ether which extracts the pungent principal, capsaicin. The indicator, which consists of a 1 per cent solution of vanadium oxytrichloride in carbon tetrachloride, is added to the ether extract until no further color change takes place. Sweet pepper extracts show no green color reaction while those of hot peppers vary from a greenish yellow to a dark green as the content of capsaicin increases.

A method is described for the preparation of a series of color standards from malachite green and napthol yellow. Variety tests indicated that considerable variation exists in capsaicin content among varieties ordinarily classified as hot. Marked variations also occur within some varieties.

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An Auxanometer for Continuous Recording of Potato Tuber Growth[1]

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STUDIES of growth in plants and plant parts are matters always of academic interest to the plant scientist and often of practical significance to the producer of crops. The value of such studies in the interpretation of plant responses to environment depends to a great extent upon the degree of refinement attained in the techniques employed. Continuous records of growth, that may be correlated with records of temperature, humidity, soil moisture or other elements of the environ-

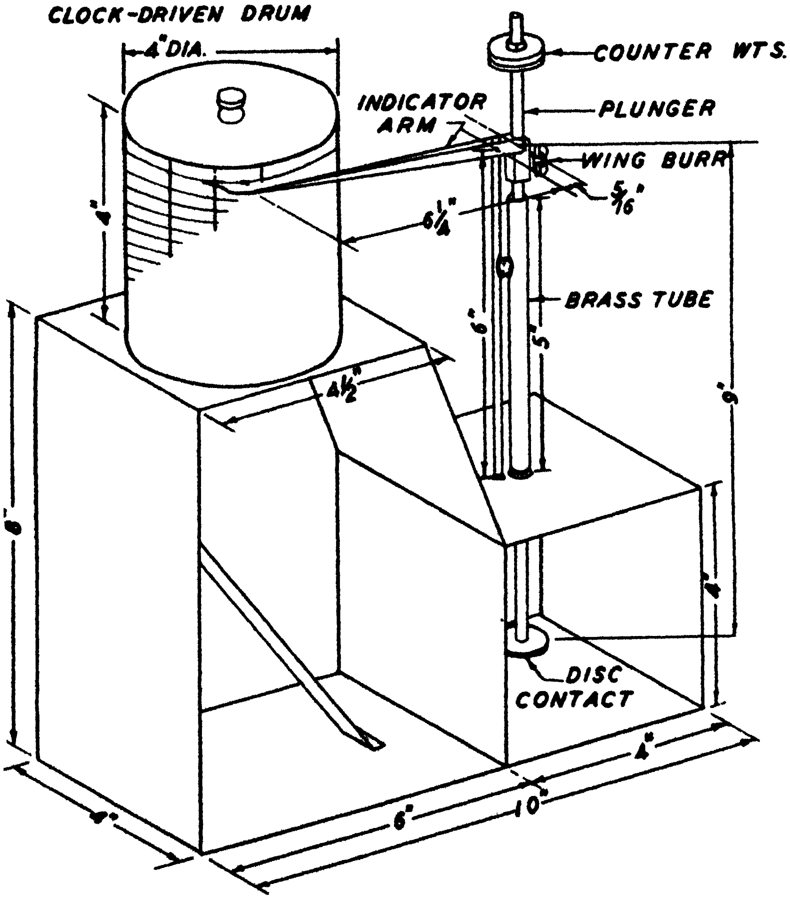

Fig. 1. Construction details of auxanometer for measuring potato tuber growth.

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[2] Resigned October 31, 1941.

mental complex, are generally most useful. This paper describes the construction and operation of an auxanometer designed to give such a continuous record of growth of a potato tuber in its natural environment. The instrument was designed at the Idaho Agricultural Experiment Station at Moscow, and was used on Russet Burbank potatoes growing at the Parma Branch Station, located in an irrigated region of the southwestern part of the state. The essential details of construction are shown in Fig. 1.

Soil is carefully removed from one side of a potato plant until a tuber and the rhizome on which it is borne are sufficiently exposed to permit the tuber to be placed on the floor of the box-like compartment, and directly under the disc. By loosening the wing burr, the plunger to which the disc is attached is disconnected from the indicator arm and permitted to move freely through the brass tube. The plunger is lowered until the disc rests on the tuber. The indicator arm is then adjusted to give the desired position of the pen on the chart fastened to a clock-driven drum. The wing burr is tightened at this position. The soil is then replaced around and over the tuber to approximately its former level, covering the disc and lower portion of the plunger. Subsequent increase in vertical diameter of the tuber results in an upward movement of the disc. This movement is transmitted through the plunger and indicator arm to the pen on the revolving drum. As the instrument is constructed, any vertical movement of the rod is magnified 20 times at the position of the pen.

The frame of this apparatus is constructed of 18 gauge stainless steel. To give added rigidity the base of the frame is reenforced by two angle braces fastened lengthwise to the bottom. These are not shown in the diagram. All joints are spot welded.

A continuous growth record of one tuber, covering a period of 5

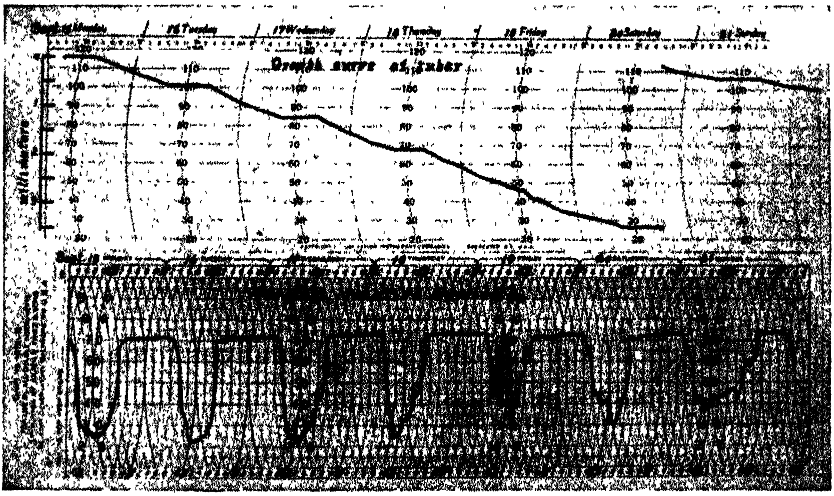

FIG. 2. Growth curve of a single potato tuber for a period of 1 week plotted against relative humidity of the atmosphere.

weeks, was secured late the growing season of 1941. The tuber was the size of a walnut at the time it was placed in the auxanometer. A typical growth curve covering 1 week of this period is reproduced in Fig. 2. A characteristic feature of the growth curve throughout most of the period covered by this study was the complete absence of growth during an appreciable part of each day. Such periods were indicated on the chart by horizontal lines traced by the pen of the indicator arm.

For 29 consecutive days previous to the occurrence of killing frost the average daily period without growth was 9 hours. Growth usually ceased rather abruptly between 7 and 10 a.m., and was resumed between 3 and 6 p.m. On one day only, September 19, was there less than a 5-hour continuous period without growth. On that day growth ceased for 1-hour intervals between 10:30 and 11:30 o'clock in the morning, between 12:00 and 1:00 o'clock and between 3:00 and 4:00 o'clock in the afternoon.

As may be seen in Fig 2, these periods without growth coincided almost perfectly with periods of low atmospheric humidity. On most days the humidity, which had maintained a fairly high level during the night, dropped abruptly about 8:00 o'clock in the morning. This drop in humidity was invariably followed shortly by cessation of growth in the tuber. Resumption of growth always occurred soon after the humidity began to rise again in late afternoon. On September 19 each of the three 1-hour periods without growth followed closely brief periods of low humidity that interrupted what would otherwise have been a sustained high level of humidity throughout the day.

The growth rate of this tuber during the first 2 weeks of the record appeared to increase with decreasing atmospheric temperatures. This was probably a mere coincidence due to an inverse relationship of temperature to relative humidity. In the latter part of the season, as the mean daily temperature lowered, there was no corresponding increase in tuber growth, which continued to parallel periods of high humidity. There was, in fact, a steady decline of the growth rate as the season advanced. For the period of this investigation the average daily diameter increase for the first 9-day interval was .39 millimeters, for the second 9-day interval .29 millimeters, and, for the last, .17 millimeters. This decline of growth rate late in the season might be attributed to the downward trend of air temperature, to the shortening photoperiod, or to other factors, none of which was observed sufficiently in this study to justify any conclusions.

It has been shown by Harley (2) and by Verner (3) that, in apples, the periods of most rapid growth correspond to periods when atmospheric evaporation rates are low. Similar observations on growth rates in pears have been reported by Aldrich and Work (1). Since atmospheric evaporation rates bear a close, inverse relationship to atmospheric humidity, the daily cessation of growth of a potato tuber, coinciding with periods of low humidity, would also be expected to coincide with periods of high evaporation rates. It appears, then, that growth of the tuber used in this study occurred only under conditions of relatively low evaporation rates favoring a relatively high level of water content of the plant tissues. Under conditions of low humidity and correspondingly high evaporation rates, which would tend materially to reduce hydrostatic pressure throughout the plant, growth of the potato ceased.

While only a single tuber was involved in this study, there is no particular reason to believe that its behavior was not essentially normal. The disc of the auxanometer, adjusted to a delicate balance by means of the counter weights at the top of the plunger, exerted no significant pressure of its own against the tuber. The resistance of the soil to continued growth certainly would be no greater than it was previous to disturbance. The looseness of the soil after replacement, and the exposure of the tuber and roots incident to installment of the auxanometer, might result in some modification of growth. However, these disturbances would be more likely to affect the ultimate size attained rather than to alter materially the growth pattern of the tuber. The marked periodicity of growth observed, and the consistent response of the growth rate to environmental change, would indicate that the recorded behavior of the tuber represented an essentially normal response to its natural environment rather than an abnormal response occasioned by the treatment to which it was subjected.

From the growth record secured over a period of 5 weeks it is evident that this auxanometer lends itself well to the study of growth of a tuber in its natural environment. It has sufficient precision to record minor variations in growth rates throughout the diurnal period. While it measures only increase in one diameter, which is not representative of volume increase, the recorded growth pattern accurately portrays fluctuations in relative growth rates. This should make the instrument useful in studying the effects of atmospheric conditions, soil moisture, sprays, and other factors suspected of influencing the growth of tubers.

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Effect of Date and Depth of Planting on Yield of Irish Cobbler Potatoes[1]

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GROWERS in the coastal vegetable area of South Carolina, begin their potato planting about February 1st and continue planting over a period of approximately 30 days. As shown in Fig. 1, temperatures are usually low and rainfall is abundant during this time. Because of this it was thought that too early planting might increase the loss from seed-piece decay. Early planted potatoes emerge about the middle of March and, in some years, unseasonable frosts cause damage to the crop.

A study of the effects of date and depth of planting on the yield of Irish Cobbler potatoes was started in 1939. Four plantings were made at 10-day intervals beginning February 1st. Two thousand pounds per acre of a 5–10–5 fertilizer was applied with a band-type potato planter. The planter-shoe was set so that the seed pieces were placed at a depth of 1 to 2 inches (shallow) or 3 to 4 inches (deep). Seed pieces were spaced 12 to 13 inches apart. In all cases beds of the same height were thrown up with a middle breaker leaving the deep-planted seed pieces covered 2 inches deeper than the shallow planted ones. Each plot consisted of two 3-feet rows, 72½ feet long, (1/100 acre). There were four or five replicates of each treatment.

The February 1st planting began to emerge between March 15th and 20th, depending on weather conditions. Plants from the early shallow-planted seed pieces emerged only 1 to 2 days earlier than the deep planted ones. As the temperature increased, the difference in time of emergence between deep and shallow planted seed pieces disappeared. The March 3rd planting began emerging only about 12 days later than the February 1st planting.

It was thought the early plantings would be more subject to frosts. No serious frosts occurred during the 3 years that the experiment was conducted. However, light frosts occurred every year. Invariably these frosts occurred after the first two plantings were up and the third and fourth plantings were emerging. Damage to the larger plants was negligible; plants just emerging were "scorched" and their development delayed. Serious frosts did occur in some sections of the potato area. They usually came after all plantings were up or in the process of emerging and time of planting seemed to offer little protection against damage.

Bushnell (1) reports better stands in earlier plantings because of less damage from hot soil. It was thought that stands from later planting would be better in South Carolina because of the shorter time between planting and emergence. No trouble was experienced with seed-piece decay in the plots, but there was a wet spot in another part of the field where seed pieces did decay. Four rows were planted through this spot on each planting date. The determining factor seemed to be the length of time that the seed pieces were in the soil in advance of heavy rains. For example 7 inches of rain occurred during the last 10 days of February 1939. The February 20th planting was seriously affected by seed-piece decay while the February 1st and 10th plantings were not greatly affected. Observations in commercial plantings indicate that two factors are involved, drainage and length of time the seed pieces are in the soil prior to the rain. Once a seed piece has started to produce sprouts and roots, it is not as likely to rot as freshly planted ones. Deep planting causes more decay than shallow planting.

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[1] Technical contribution No. 89 from the South Carolina Experiment Station.

The yields reported in Table I indicate that Irish Cobbler potatoes planted the first half of February may be expected to produce significantly greater yields than those planted February 20th or later. Bushnell reported that plantings in April and May yielded more than those in June. The period during which variation in planting dates seems to make little difference in yield under Ohio conditions, is much greater than that in South Carolina. There is a consistent tendency for early, shallow-planted potatoes to yield more than those planted deep on the same date. This difference is less than the experimental error and therefore is not significant. This probably means that 2 inches is deep enough for seed pieces to be planted and 3 to 4 inches is approaching the danger point. Observations indicate that the critical point will vary with such factors as soil type and drainage. The shallow planting was deep enough to prevent sunburn such as was reported by Moore (2).

TABLE I—EFFECT OF DATE AND DEPTH OF PLANTING ON YIELD OF IRISH COBBLER POTATOES

Planting Date	Depth	Yield of U. S. No. 1's (100-Lb Bags)			
		1939	1940	1941	Average
Feb 1	Shallow	103	92	81	92
Feb 1	Deep	89	77	77	81
Feb 10	Shallow	88	61	60	70
Feb 10	Deep	82	51	62	65
Feb 20	Shallow	72	58	46	59
Feb 20	Deep	60	56	30	49
Mar 3	Shallow	63	52	34	50
Mar 3	Deep	66	58	33	52
Difference required for significance		16	16	26	16

The climatic data presented in Fig. 1 explain in part why the response to time of planting was so marked. Plants from the earliest planting emerged less than 2 weeks ahead of the latest planting. During this period temperature and moisture conditions were very favorable for rapid growth. As the season advanced, rising temperatures increased the loss of moisture through transpiration and evaporation. Since rainfall decreased as the growing season advanced, moisture became the limiting factor in plant growth during the period of this investigation. This was especially true during the 40 day period beginning April 10th and continuing to harvest time (May 20th). It was during this period that tuber enlargement took place. According to the rainfall curves by 10-day intervals potato growers may expect a hot dry spell during this 40-day period. The monthly curves do not reveal

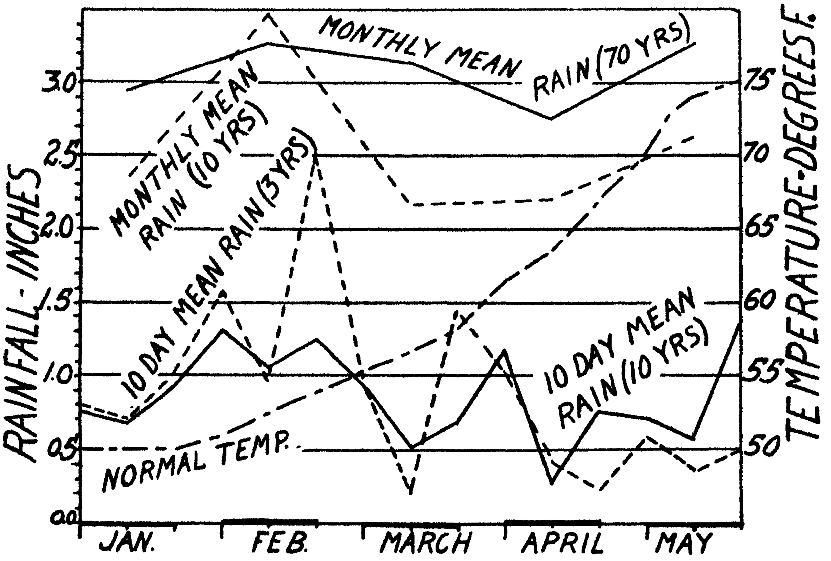

FIG. 1. Weather data for the potato season at Charleston, South Carolina. At bottom — rainfall by 10-day intervals for the 3-year period (1939 to 1941) the experiment was conducted and for comparison the 10-year period 1932 to 1941). At top — Monthly means for this same 10-year period is compared with the 70-year record of the local weather bureau. The normal temperature is also given by 10-day intervals.

this fact quite as strikingly since summer rains frequently begin during the last 10 days of May. The early planted potatoes make their maximum growth before the moisture supply becomes critical whereas the late plantings suffer serious injury. This was borne out by the premature ripening of the last plantings which were ready to harvest within a week after the earliest plantings. Further evidence of this fact is found in the 1941 yields which were especially low for the late plantings. During 1941 there was only 0.32 inches of rain from April 10th to May 20th.

CONCLUSION

Potatoes planted the first 2 weeks of February in South Carolina coastal vegetable sections may be expected to produce more than those planted the last half of the month. Seed pieces should be planted in a furrow about 2 inches deep and covered in the usual manner. The normally low rainfall that occurs during a 40-day period beginning April 10th and continuing to May 20th, in conjunction with high temperatures, is probably the chief factor responsible for this marked response to time of planting.

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A Comparison of Stands and Yields from Seed Pieces Cut from the Apical and Stem Ends of Irish Cobbler, Russet Rural, and Chippewa Potatoes

By N. K. Ellis, *Purdue University, Lafayette, Ind.*

POOR or reduced stands of Chippewa and Katahdin potatoes have been reported each year by growers who always get good stands of Irish Cobbler potatoes. Since these reports are often from growers with acreages so large that their seed piece preparation is not under their direct supervision, this trial was established to determine what part of the loss in stand could be attributed to cutting of the seed.

Lombard and Stuart (2) concluded that there was no difference in the relative vigor of eyes taken from different parts of the potato. In their experiment, however, the varieties used were Cobbler and Green Mountain and the pieces were allowed to cork over. Appleman (1) concluded that all eyes on a tuber had equal vigor, but in his experiments he used the Irish Cobbler and McCormick varieties, which are known to have deep eyes, well distributed over the surface of the potato.

The experiment reported here was designed to simulate ordinary seed cutting practices. The average worker cuts for size of the seed piece rather than to observe whether each piece has an eye in it. Many growers have instructed those cutting the seed to discard pieces which have no eyes, but only a small number of pieces are discarded. The common practice is to plant soon after cutting of the seed pieces.

Three varieties of potatoes were used: Irish Cobbler (early), Chippewa (midseason), and Russet Rural (late). Tubers were selected for uniform size, and cut into four equal parts, cutting once through the

TABLE I—Rate of Emergence of the Hills of Irish Cobbler, Russet Rural, and Chippewa Potatoes Grown From Seed Pieces Cut From the Apical and Stem End of the Tubers

Days After Planting	Number Hills Apical End Pieces	Number Hills Stem End Pieces
Irish Cobbler		
14	24	11.4
21	25	21.6
29	25	24.2
34	25	24.7
Russet Rural		
14	Not up	Not up
21	24.3	11.5
29	24.9	22.2
34	24.9	23.7
Chippewa		
14	21	1.4
21	23.7	9.0
29	24.2	14.5
34	24.5	22.0*

*10.8 per cent of the 22 hills which emerged did not produce tubers of marketable size.

apical end and once laterally. The average weight of the resultant seed pieces was: Irish Cobbler 1.6 ounces, Chippewa 1.43 ounces, and Russet Rural 1.35 ounces. All tubers were cut and planted the same day as is the common practice of growers on muck soil. All three varieties were planted May 27, 1941, and each treatment was replicated 10 times in 25-hill rows. Table I gives the hill count on four different dates after planting. In all cases plants from the pieces cut from the basal ends were slower in emerging than were plants from the apical pieces; however, all but about 1 per cent of the plants of Cobbler finally came through and at the end of the season there was no significant difference in the weight of the dry vines of Cobbler. The yield, as shown in Table II, gave 362 bushels of No. 1 size tubers per acre for the pieces cut from the apical ends and 340.7 bushels per acre for the pieces cut from the stem ends of the tubers. The difference in yield was barely significant at the 5 per cent level.

The Russet Rural was generally slower than either Irish Cobbler or Chippewa in emerging. The final stand for the pieces from the bud end was 99.6 per cent, the stand from the stem end 94.8 per cent. The final yield of No. 1 size tubers was 270.8 bushels per acre for the pieces from the bud ends and 218.7 for the pieces from the stem ends. The differences in yield are highly significant at the 5 per cent level of significance. The yield data are given in Table II.

TABLE II—YIELD OF NO. 1 SIZE POTATOES FROM SEED PIECES CUT FROM THE APICAL AND STEM ENDS OF IRISH COBBLER, RUSSET RURAL AND CHIPPEWA POTATOES*

Variety	Apical End Pieces (Bu. Per Acre)	Stem End Pieces (Bu. Per Acre)	Difference In Yield (Bu. Per Acre)	Least Difference For Significance (Bu. Per Acre)
Irish Cobbler	362.0	340.7	21.3	21.0
Russet Rural	270.8	218.7	52.1	21.8
Chippewa	259.4	132.0	127.3	20.5

*Planted May 27, 1941.

In spite of its good yield under field conditions, the Chippewa is known as a weak sprouting variety on muck soils. Two per cent of the apical pieces did not grow as compared with 12 per cent of the stem end pieces and an additional 10.8 per cent of the pieces cut from the basal end were too weak to produce marketable potatoes. This may readily account for much of the 20 per cent loss in stand, annually reported by growers of Chippewa. The yield as shown in Table II is more interesting; 259.4 bushels per acre produced from seed cut from the apical end, and 132.1 bushels per acre from stem end pieces. If the yield from the stem end were corrected for stand on the basis of the 22.8 per cent of unproductive hills the yield would be only 171.1 bushels of No. 1 size tubers per acre. The difference in yield is highly significant.

On the basis of these data, it is suggested that there may be a difference between varieties in their reaction to apical dominance of the seed pieces. Since practically all of the new varieties which have been released have shallow eyes and fewer eyes on the stem end, it would be well to study their requirements for seed piece preparation. For the grower of Chippewa in particular, it might be suggested that he buy seed selected for its size, 3 to 4 ounces preferred, and cut the tuber only once, through the apical or bud end. This should produce uniform stands and higher yields.

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Some of the Factors Affecting the Carotene Content of Sweet Potatoes[1]

By Julian C. Miller and Henry M. Covington, *Louisiana Agricultural Experiment Station, Baton Rouge, La.*

CONSIDERABLE variation has frequently been noticed in the color of the skin and flesh of the Porto Rico variety of sweet potato when grown in different soil types and in different sections. There are many factors which may be responsible for the differences in color, namely: (a) environmental influences such as moisture, temperature, photoperiod, and variations in soil type; (b) cultural practices such as height of bed and fertilizers; (c) storage; and (d) hereditary influences.

In order to study some of the factors affecting carotene, the following experiments were set up and conducted during 1940: (a) effect of storage, and (b) effect of heredity.

Fraps (1) reports 70 units of vitamin A in sweet potatoes as determined by the Sherman-Munsell (9) method. Lease and Mitchell (4), working with Porto Rico sweet potatoes, report an average of 40 micrograms of carotene per gram of fresh sample, and 130 micrograms of carotene per gram of sample on dry weight basis. McLeod, Talbert, and Toole (6) report a vitamin A value of 30 units per gram of sample for the Nancy Hall variety of sweet potato, using the biological assay method. According to Fraps and Treichler (2), using the biological assay method, the vitamin A content of raw Porto Rico sweet potatoes was 30 to 50 rat units (one rat unit of vitamin A is approximately the same as an international unit[2] of vitamin A). McLeod, Armstrong, Heap, and Talbert (5), working at the Tennessee Agricultural Experiment Station using the biological assay method, found that the Porto Rico variety contained about 20 units of vitamin A at the time of harvesting. After 2 months in storage, the vitamin A content increased to 65 units, which they attribute to changes taking place in the sweet potato during storage. Swanson, Stevenson, and Nelson (10), working with canned Marglobe tomatoes, found an average concentration of 5.7 units of vitamin A per gram, whereas fresh Marglobe tomatoes contained 3.3 units per gram. They gave no definite reason for increase in the canned fruit, but suggested that processing may have rendered the vitamin A more available.

Materials and Methods

In all studies other than those involving seedlings, potatoes of the Porto Rico variety were used and grown on Lintonia silt loam at Louisiana State University. A bushel of roots was saved from each treatment for sampling purposes. In all cases only U. S. No. 1 roots, conforming to the same general shape and size, were used. To obtain a sample for extraction of carotene, a longitudinal V-shaped section cut from each of 10 roots was finely ground and thoroughly mixed. All samples were run in duplicate. The values given in this paper are the average of two samples representing 10 colorimeter readings (five readings taken on each sample). The method used in this experiment for the extraction of carotene is a slight modification of that outlined by Zimmerman, Tressler, and Maynard (11), working at Cornell University. These chances were as follows:

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[1] At the time this work was conducted Henry M. Covington was an Agent for the United States Department of Agriculture, Bureau of Plant Industry.

[2] One international unit of vitamin A is equivalent to the activity of 0.6 micrograms of the International Standard of Reference. This standard of reference is pure beta-carotene which conforms to the requirements given for chemical and physical constants.

By tests using the spectrophotometer it was found that no chlorophyll was present in the Porto Rico sweet potatoes at the time of harvest. For this reason the portion of the method used for the extraction of chlorophyll was eliminated.

The carotene was determined by using a Klett colorimeter. The standard was made up as prescribed by Guilbert (3). Since it has been reported by Matlack (7) that practically all the carotene in the sweet potato roots is in the beta form, the dye solution was standardized against pure beta-carotene.

EXPERIMENTAL RESULTS

The Effect of Storage on the Carotene Content of Porto Rico Sweet Potatoes:—A bushel sample was selected from each of seven randomized plots. These potatoes were harvested on October 17, cured, and placed in storage under conditions recommended for this crop. A carotene determination was made from each sample at the time of harvest, and at monthly intervals thereafter until January 17.

The data presented in Table I show that there was a significant increase in carotene content after the first and second months in storage, however, the carotene in the third month showed a slight decrease over that in the second month but the differences was not significant. Even after 3 months in storage the carotene content was significantly higher than at the time of harvest.

TABLE I—THE EFFECT OF STORAGE ON THE CAROTENE CONTENT OF PORTO RICO SWEET POTATOES

Time of Determination	Amount of Carotene* (Micrograms Per Gram Sample)
At harvest	51 0
One month after harvest	75.3
Two months after harvest	81.9
Three months after harvest	80.2

*Difference required for significance =5.6.

Breeding for High Carotene Content of Sweet Potatoes:—Miller (8) at the Louisiana Agricultural Experiment Station has been breeding sweet potatoes since 1937. One of the purposes of this work is to breed a sweet potato having a very high carotene content. To accomplish this several thousand seedlings have been grown resulting from crosses made between the present varieties having yellow flesh color. Since the sweet potato has a large number of chromosomes and the varieties used as parents are heterozygous, there is much segregation even in the F_1 generation hybrids.

TABLE II—CAROTENE CONTENT OF SWEET POTATO SEEDLINGS AND THEIR PARENTS

Seedling or Variety	Carotene Content*	Seedling or Variety	Carotene Content*
1 ×6–39–2	87.8	32–87-20	96.4
1 ×6–39–5	151.5	32–106–25	41.8
1 ×42–39–3	57.6	32–149–36	85.1
1 ×6–38–14	41.3		——
3 ×6–39–2	86.4	*Selected Parents*	——
3 ×7-39-1	72.2	Unit I Porto Rico (No. 1)	76.3
6 ×1–39–6	87.9	Nancy Hall (No. 6)	28.3
7 ×63–39–4	129.5	47442 (No. 42)	27.6
42 ×6–39–12	140.4	U. S. 291 (No. 63)	A trace
32-10–5	102.1	Creole (No. 7)	14.7

*Micrograms per gram of sample.

As shown in Table II the carotene content is given for some of the better 1938 and 1939 F_1 seedlings selected for edible qualities and also the carotene content of some of the standard varieties used as parents in these crosses. It is evident from these data that the carotene content of sweet potatoes can be greatly increased by breeding. This is shown by several of the seedlings which have 100 micrograms or more of carotene per gram sample, and several of the seedlings have twice the carotene content of the parent varieties.

DISCUSSION

Although the data show an increase of carotene in Porto Rico sweet potatoes stored 2 months, there is at present no explanation for this increase. It cannot be explained on the basis of increased dry matter for it is well known that changes in dry matter content during curing and storage are insufficient to account for the increase in carotene obtained.

These data show an average carotene content of 51.0 micrograms per gram of sample at time of harvest, and 81.9 micrograms after being stored 2 months. Lease and Mitchell (4) report that the average carotene content of Porto Rico sweet potatoes is 40 micrograms per gram of sample (fresh weight basis) and 130 micrograms expressed on dry weight basis. Fraps (1) reports 70 units of vitamin A per gram of sample, which is equivalent to 42 micrograms per gram sample. The latter was determined by biological assay method. These differences in the amounts of carotene reported from different sections of the country and obtained by different techniques suggest that there are many factors that influence the carotene content of sweet potatoes, even of the same variety. In this work no check on the chemical determinations of carotene was made by using the biological assay method.

SUMMARY AND CONCLUSIONS

The carotene content of Porto Rico sweet potatoes increased rapidly during the first month of storage. There is a gradual increase during the second month of storage, after which time there is a trend for the carotene content to remain constant.

Although the carotene content of sweet potatoes may be materially changed by environmental factors and cultural practices, the most feasible means of increasing the carotene content is by hybridization.

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Nutrient Absorption by a Summer Crop of Lettuce in Salinas Valley, California

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ONLY limited information is available regarding the course of nutrient absorption during the growth of vegetable crops. The period of growth at which the maximum absorption or utilization of nutrients occurs is definitely related to crop fertilization, particularly to the time of fertilizer application. Studies regarding the time of nutrient absorption are of value also in determining the efficiency of the crop in utilizing nutrients applied to the soil. This paper is the first in a series studying the course of nutrient absorption by spring, summer, and fall lettuce grown on Salinas Valley soils. Lettuce plants were sampled at approximately 2-week intervals from the time the plants were an inch high until market maturity, when the plants were harvested. Only the top portion of the plant cut level with the soil surface was used for the study. The plants were grown on a soil classified as Salinas silty clay loam. This soil is typical of the Salinas Valley soils used for the production of summer lettuce, and had previously produced a spring crop of lettuce which was fertilized with 200 pounds of nitrate of soda per acre. The samples were taken from a fertilizer test in which different nutrient levels were studied. In agreement with common practice two rows of lettuce thinned to 12 inches apart in the row were grown on beds 3 inches high and 40 inches from center to center. The fertilizer was applied as a side dressing just before thinning the plants, 2 inches outside the row and approximately 5 inches deep. Approximately 14 acre inches of water were used to grow the crop of which 6 inches were used to "irrigate up" the seed. Three later irrigations of 2 to 3 acre inches each were applied on July 21, August 8, and August 31.

There were no differences in size of head or per cent cut for any of the fertilizer treatments and chemical data are presented only for those treatments which were considered most likely to show physiological differences within the plant. The data in Table I present the results of analyses of the soluble nutrients in the midrib of the wrapper leaves. Each sample constituted a composite of wrapper leaves taken from 10 plants in each plot. The figures reported are the averages of single samples from two plots of each fertilizer treatment. Samples were taken at approximately 10 o'clock each morning. The plant sap was extracted in 2 per cent acetic acid and phosphorus and nitrogen were estimated from the extract according to the methods outlined by Carolus (1). Potassium was determined volumetrically by the cobaltinitrite method.

At the first two dates of sampling there were no consistent differences in nitrate nitrogen or total soluble nitrogen content in plants from any of the fertilizer treatments but at the last two dates of sampling these constituents were considerably lower in plants from plots not receiving fertilizer or from those receiving only 120 pounds of

TABLE I—EFFECT OF FERTILIZER TREATMENTS ON THE SOLUBLE NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF LETTUCE PLANTS, SUMMER 1941 (ALL FERTILIZERS APPLIED BEFORE THINNING)

Treatments (Acre Basis)	Parts Per Million of Soluble Nutrients in Midrib—Expressed on Fresh Weight Basis			
	Aug 5	Aug 24	Sep 4	Sep 18
Nitrate nitrogen as N				
1. Check, no fertilizer	239	400	155	140
4. 300 pounds 16–20–0	436	370	285	328
6. 240 pounds ammonium sulfate	375	413	268	223
7. 120 pounds ammonium sulfate	263	297	155	185
8. 480 pounds ammonium sulfate	241	495	298	552
9. 300 pounds nitrate of soda	233	495	295	250
10. 600 pounds 8–10–8	233	395	283	175
Total soluble nitrogen as N				
1. Check, no fertilizer	431	548	245	255
4. 300 pounds 16–20–0	784	525	423	487
6. 240 pounds ammonium sulfate	518	638	455	440
7. 120 pounds ammonium sulfate	764	468	292	328
8. 480 pounds ammonium sulfate	590	663	505	758
9. 300 pounds nitrate of soda	574	645	533	428
10. 600 pounds 8–10–8	709	538	465	308
Potassium oxide as K_2O				
1. Check, no fertilizer	—	4480	5115	5365
4. 300 pounds 16–20–0	—	4755	4835	4895
6. 240 pounds ammonium sulfate	—	4525	5010	4550
8. 480 pounds ammonium sulfate	—	4330	4575	5305
10. 600 pounds 8–10–8	—	4645	4540	4345
Phosphorus as P				
1. Check, no fertilizer	236	200	127	150
4. 300 pounds 16–20–0	237	200	132	156
6. 240 pounds ammonium sulfate	199	194	131	137
8. 480 pounds ammonium sulfate	229	199	133	150
10. 600 pounds 8–10–8	211	190	119	131

ammonium sulfate per acre. At the last sampling date soluble nitrogen was also low in plants grown in plots receiving a complete fertilizer. Even the lowest level of nitrogen in the plant sap was not associated with a decreased plant yield. Plants from plots receiving 480 pounds of ammonium sulfate per acre were by far the highest in soluble nitrogen at the end of the season. Potassium remained high and practically constant in all samples during the entire season. Applying extra potassium to the soil did not result in increased soluble potassium content of the plants. Soluble phosphorus decreased in all samples as the plants approached market maturity. Applying phosphorus to the soil did not increase the amount found in the plants as compared to that found in plants grown on plots not receiving phosphorus. Applications of nitrogen to the soil did not affect the phosphorus or potassium content of the plants. Carolus (1) reports lettuce plants grown in Virginia as containing 589 parts per million of nitrate nitrogen, 42 of phosphorus, and 650 of potassium oxide. Thus the plants grown at Salinas were slightly lower in nitrogen but about five times as high in phosphorus, and eight times as high in potassium, indicating a high content of phosphorus and potassium in the soil used in this experiment. This undoubtedly accounts for the fact that there was no response either in yield or plant nutrient content from phosphorus or potassium applications to the soil.

TABLE II—NUTRIENT CONTENT OF LETTUCE PLANTS AT VARIOUS STAGES OF GROWTH, SUMMER 1941 (DATA ARE EXPRESSED ON BOTH FRESH WEIGHT AND DRY WEIGHT BASIS)

Nutrient	Percentage Composition on the Following Dates									
	Fresh Weight Basis					Dry Weight Basis				
	Jul 17	Aug 5	Aug 24	Sep 4	Sep 18	Jul 17	Aug 5	Aug 24	Sep 4	Sep 18
Nitrogen—N	——	.396	.283	.188	.150	——	3.69	4.04	3.12	2.65
Phosphorus—P	.043	.035	.028	.027	.021	.45	.33	.41	.45	.37
Potash—K_2O	.701	.667	.547	.398	.369	7.42	6.22	7.81	6.60	6.51
Lime—CaO	.341	.242	.170	.115	.095	3.57	2.26	2.43	1.90	1.67
Ash	2.47	2.64	1.72	1.13	.90	25.87	24.63	24.57	13.74	15.89

The data in Table II give the analyses of the total nutrient content of the entire top portion of plants from the treatments listed in Table I. Nitrogen was determined on the dried plant material by the Kjeldahl method using the nitrate modification. Phosphorus, potassium, and calcium were determined from ashed samples. Phosphorus was determined colorimetrically using the molybdate method. Calcium was estimated volumetrically by titration of the oxalate, while potassium was determined volumetrically by the cobaltinitrite method. The data are expressed on the basis of both fresh weight and dry weight because the water content of the plants was found to increase considerably as the plants approached market maturity. Since, with only one exception, the percentages of nitrogen, phosphorus, or potassium in the plant were essentially the same in all treatments regardless of the fertilizer added, all treatments of Table I were averaged in obtaining the data reported in Table II. Each figure thus represents the average of 14 determinations made on composite 10-plant samples from two plots of each treatment. The one exception was that plants from treatments eight where 480 pounds of ammonium sulfate per acre were applied to the soil were higher in total nitrogen at all stages of growth than were plants from any other treatment. At the four successive sampling dates the percentages of total nitrogen on the fresh weight basis in plants of this treatment were 0.414, 0.304, 0.217, and 0.179 per cent as compared to 0.319, 0.275, 0.169, and 0.149 per cent in plants from plots not receiving nitrogen. When expressed on the basis of percentage of fresh weight all nutrients analyzed became lower as the plants approached market maturity. This was particularly true for calcium and total ash. Phosphorus and potassium were approximately half as high in mature plants as in plants in the early stages of growth. The decrease on the fresh weight basis was due largely to a higher water content as the plants attained maturity. When the data were expressed on the basis of percentage of dry weight, calcium and ash showed marked decreases with maturity, while nitrogen decreased slightly. The phosphorus and potassium contents were practically constant at all stages of growth on the dry weight basis. McGeorge *et al.* (2) report analyses of lettuce plants grown in Arizona "where the calcium and phosphorus content remained closely a constant percentage throughout the growth of the plant", but nitrogen and potassium fluctuated somewhat with nitrogen showing a decrease as the plants approached maturity.

Data showing the growth and the amount of nutrients removed at the different stages of growth are presented in Table III. During the 2 months period after planting from June 23 to August 24 the plants made little growth but during the next 3 weeks the plants increased about seven times in weight. The latter period coincided with the stage of maximum heading, as the plants approached market maturity. When the plants had begun to head by August 24 they had removed from the soil only 9.6 pounds of nitrogen per acre, 1.1 pounds of phosphorus, 20.7 pounds of potash and 6.4 pounds of lime. This would indicate that only a relatively low concentration of nutrients in the soil would suffice until time of heading and that the common practice of waiting until thinning the lettuce before applying fertilizer is justified in the summer crop. The entire crop when harvest was completed on October 16 had absorbed 47 pounds of nitrogen per acre, nearly 7 pounds of phosphorus, 117 pounds of potash, and 30 pounds of lime.

TABLE III—GROWTH AND TOTAL POUNDS PER ACRE OF NITROGEN, PHOSPHORUS, POTASSIUM, AND CALCIUM REMOVED BY A SUMMER CROP OF LETTUCE IN SALINAS VALLEY, SUMMER 1941

Matters Under Consideration	Date of Sampling					
	Jul 17	Aug 5	Aug 24	Sep 4	Sep 18	Oct 6
Growth (pounds of fresh weight per acre)	31.9	365	3782	14556	25351	31662
Dry matter as per cent of fresh	9.54	10.72	7.00	6.03	5.67	5.67
Pounds of nutrients removed per acre:						
Nitrogen—N	——	1.43	9.64	24.59	37.65	47.02
Phosphorus—P	.01	.12	1.08	2.99	5.40	6.74
Potash—K_2O	.23	2.44	20.68	58.02	80.57	116.70
Lime—CaO	.11	.88	6.43	16.66	24.14	30.02

Seed planted on June 23, 1941 and irrigated immediately; plants thinned on July 26, 1941; first cutting September 11, 1941; last cutting October 16, 1941; 21,250 plants per acre.

SUMMARY

The soluble nutrients in the sap of the midrib of the wrapper leaves and the total nutrient content of the top portion of a summer crop of lettuce, at various stages of growth were studied. The nitrate nitrogen in the midrib of the wrapper leaves of plants grown on plots not receiving nitrogen varies from approximately 240 parts per million 2 weeks after thinning to a low of 140 parts per million at the time of market maturity. Plants from plots receiving 480 pounds of ammonium sulfate per acre contained 500 parts per million of nitrate nitrogen at the time of market maturity. The soluble potash content was high and remained constant throughout the season averaging approximately 4,800 parts per million. Soluble phosphorus decreased somewhat with maturity averaging about 225 parts per million 2 weeks after thinning and decreasing to about 150 parts per million at market maturity. Adding phosphorus or potassium to the soil did not increase the content of either of these elements in the plant.

In the entire top portion of the plant all nutrients decreased as the plants approached market maturity on the basis of fresh weight determinations. On the dry weight basis, calcium and ash showed marked decreases with maturity, and nitrogen a slight decrease, while phosphorus and potassium remained practically constant throughout growth. At market maturity on the basis of dry weight determinations the plants averaged 2.65 per cent nitrogen, 0.37 per cent phosphorus, 6.51 per cent potash (K_2O), 1.67 per cent lime (CaO), and 15.89 per cent ash.

Lettuce plants when they had begun to head had absorbed 9.6 pounds of nitrogen per acre, 1.1 pounds of phosphorus, 20.7 pounds of potash and 6.4 pounds of lime. The entire crop at market maturity had absorbed 47 pounds of nitrogen per acre, 7 pounds of phosphorus, 117 pounds of potash, and 30 pounds of lime.

LITERATURE CITED

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Use of Electricity in Curing and Storing Sweetpotatoes

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THE sweetpotato storage house of the Department of Horticulture, Clemson Agricultural College, was equipped with electric strip heaters in the summer of 1938. During previous years this house had been heated by a coal stove. The use of a stove as a source of heat was unsatisfactory since fluctuations in temperature were quite wide between the center of the house where the stove was situated and the walls. This wide fluctuation in temperature induced undue shrinking and rotting of the roots. In addition, the stove required considerable attention, particularly during cold weather.

To secure information on the amount of electricity required to maintain proper temperatures and on fluctuations in temperature and humidity during various periods of storage and in various parts of the house, data were obtained during the curing and storage periods of 1938–39, 1939–40, and 1940–41. The results should be helpful to growers of sweetpotatoes and operators of storage houses who are interested in the use of electricity as a source of heat for curing and storing.

The house in which the tests were made is 20 feet long and 16 feet wide and has a total capacity of approximately 900 bushels. The foundation is a concrete wall 3 feet high and 6 inches thick. The walls are 13 feet high and consist of 2 by 4 studs to which are attached sheeting and building paper on the outside and sheeting on the inside. The house has two floors, a solid floor and a false floor. The solid floor consists of tightly packed clay soil. The false or slatted floor is made of 1- by 4-inch boards placed 5 inches on center supported on 2- by 4-inch joists. This false floor rests on 2- by 8-inch stringers placed on edge 24 to 30 inches apart. The ceiling is 13 feet high and consists of sheathing nailed to 2- by 4-inch joists. The roof of the house consists of 2- by 4-inch rafters carrying 1- by 6-inch sheeting and galvanized roofing.

The house is divided into three rooms. The size and location of the electric strip heaters and the number of vents of each room are shown in Table I. Each bottom vent consists of two lines of 8-inch tile run from the foundation to the heater. The outside ends of the tile are fitted with doors to regulate the intake of cool air. The top vents are located in the ceiling of each room and are fitted with doors which are opened and closed by means of ropes.

TABLE I—Dimensions, Capacity, Heating and Ventilating Equipment of Storage Rooms

Room	Dimensions		Capacity (Bushels)	Voltage and Location of Strip Heater				Number Vents	
	Length (Feet)	Width (Feet)		Number	Over Vent	Number	Not Over Vent	Top	Bottom
1.......	7	6	150	1	750	0	0	1	1
2.......	11	9	210	1	1000	1	500	1	1
3.......	15	7	550	2	1000	1	500	1	2

The period during which the potatoes were in the storage house is divided as follows: (a) the curing period; (b) the post-curing period and (c) the storage period. During the curing period temperatures from 78 to 85 degrees F were maintained. Investigations have shown that high temperatures combined with high relative humidity promote rapid healing of the bruised surfaces and rapid thickening of the skin. During the post-curing period temperatures were gradually lowered from 80 to 55 degrees F over a period of about 10 to 14 days. During the actual storage period temperatures were maintained between 50 and 55 degrees F. In all of these periods the relative humidity was maintained at a high level between 78 and 96 per cent. This comparatively high humidity was obtained by wetting down the clay floor. For any one season from three to six applications of water were necessary.

The data, presented in Table II, show that from 0.37 to 0.60 kilowatt-hour of electricity was necessary to cure each bushel of sweetpotatoes in 1939–40 and 1940–41 and slightly more than 1 kilowatt-hour was necessary in 1938–39. The greater quantity of electricity used in 1938–39 was undoubtedly due to the difference in weather of the periods during which the roots were harvested. Harvesting began 2 weeks earlier and was performed during warmer weather in 1939–40 and 1940–41 than in 1938–39. Evidently, curing is more economical of electricity when harvesting of the roots is done during warm weather than when done during cool weather.

TABLE II—KILOWATT-HOURS OF ELECTRICITY USED IN SWEETPOTATO STORAGE HOUSE (1938–39, 1939–40, AND 1940–41)

Room	Total Bushels in Room	Total Kilowatt-Hours Per Bushel								
		Curing Period			Storage Period			Entire Period		
		1938–39	1939–40	1940–41	1938–39	1939–40	1940–41	1938–39	1939–40	1940–41
1.	150	1.10	0.55	0.51	1.99	2.72	2.49	3.09	3.27	3.00
2.	210	1.09	0.37	0.60	1.28	1.74	1.16	2.37	2.11	1.78

The data also show that for the storing period a greater quantity of electricity was necessary to maintain the required temperature in 1939–40 than in 1938–39. This difference is due principally to the difference in temperature between the two seasons. The winter of 1939–40 was much colder than that of 1938–39. Adequate insulation of storage houses against cold is therefore necessary.

The greater amount of electricity used in room 1 as compared with that used in room 2 is due largely to the size and difference in exposure of the two rooms. Room 1 is small and is located in the northwest side of the house and room 2 is larger and is located in the southwest side of the house. Undoubtedly size and exposure affect the amount of electricity required to maintain the required temperatures.

The data, presented in Table III, show that the electric strip heaters maintained the tempeatures required for the various periods of storage. Rather narrow but consistent differences in temperature are evident between 8:00 a.m. and 5:00 p.m. and between the upper and lower levels of the storage rooms. In all cases the mean temperature was slightly higher at 5:00 p.m. than at 8:00 a.m. and higher at the upper level than at the lower level. These differences between the upper and lower levels are much less than those which occur in stove-heated houses. Thus a marked advantage of using electricity is the maintenance of practically uniform temperatures throughout the storage house.

TABLE III—MEAN TEMPERATURE OF ROOMS IN SWEETPOTATO STORAGE HOUSE DURING VARIOUS PERIODS (1940–41)

Room	Position of Thermometer	Mean Temperature (Degrees F.)							
		Curing		Post-Curing		Storage		Entire Period	
		8 A.M.	5 P.M.	8 A.M.	5 P.M.	8 A.M.	5 P.M.	8 A.M.	5 P.M.
1	Top	82.5	84.8	72.1	75.1	55.1	57.1	57.6	59.8
	Bottom	79.6	81.6	66.4	68.7	51.9	53.3	54.2	55.9
2	Top	81.4	84.6	70.4	75.6	53.4	56.9	56.5	60.2
	Bottom	80.3	81.8	65.9	68.3	52.5	53.7	55.4	56.6
3	Top	79.5	83.8	68.0	72.2	53.8	56.4	56.7	59.5
	Bottom	77.4	80.1	65.2	67.2	51.9	53.3	54.7	56.2

The data, presented in Table IV, show the mean maximum and mean minimum temperatures and mean relative humidity in room 2 for the various periods of storage. They show that a practically constant temperature and a fairly constant relative humidity were maintained. A constant temperature combined with a constant relative humidity is favorable for long storage life of the roots. Conversely, fluctuations in temperature induce wide fluctuations in relative humidity which in turn lower the keeping ability of the roots. A comparatively high humidity is more favorable for the storage life of the roots than a comparatively low humidity since a low humidity induces excessive shrinkage of the roots. These results show that a high relative humidity can be maintained during the curing and storage period by the proper application of water to a dirt floor.

TABLE IV—TEMPERATURE AND RELATIVE HUMIDITY IN ROOM 2 IN SWEETPOTATO STORAGE HOUSE, 1939–40 AND 1940–41)

Period	Mean Temperature (Degrees F.)						Mean Relative Humidity (Per Cent)					
	Maximum		Minimum		Mean		Maximum		Minimum		Mean	
	39–40	40–41	39–40	40–41	39–40	40–41	39–40	40–41	39–40	40–41	39–40	40–41
Curing	82.3	83.8	78.7	80.2	80.5	82.0	96.1	85.0	86.0	71.2	91.0	78.1
Post-Curing	72.6	74.5	68.5	69.3	70.5	71.9	89.7	73.9	79.2	67.9	84.5	70.9
Storage	54.5	56.4	52.7	53.0	53.6	54.7	83.4	85.3	79.2	80.2	81.3	83.4
Entire	57.9	58.8	55.8	55.3	56.8	57.1	84.8	84.3	79.7	78.9	82.2	82.1

Foliar Diagnosis in Relation to Irrigation

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OUR field investigations on foliar diagnosis have been confined, thus far, to those crops which are grown under natural conditions of water supply. The method is now being extended to the examination of the nutrition of the vegetable crops in the irrigation experiment of this experiment station, details of which are given elsewhere. This paper presents the results of the periodic analysis during the growth cycle of morphologically homologous leaves of snap beans (*Phaseolus vulgaris*) grown on four differentially fertilized plots from each of two tiers, one tier being left unirrigated and the other receiving moderately heavy irrigation, amounting, during the growth period, to 4.14 inches. The precipitation as rain during the period was 6.01 inches.

The beans (variety Bountiful) followed beets. The fertilizer was a 4–16–4 commercial grade which was applied at four levels, namely, 0, 500, 1000, and 2000 pounds to the acre. Two thirds of these quantities were applied to the beets and the remainder to the beans at the time of planting on July 26.

THE EFFECT OF IRRIGATION ON THE NITROGEN AND ASH CONSTITUENTS

The plot numbers, treatments, and yields of green pods are shown in columns 1 to 4 of Table I. In columns 5 to 9 are given the percentages of N, P_2O_5, K_2O, CaO, and MgO, respectively, in the dried foliage. The analytical data represent, in all cases, the mean of the values from samples of the first leaf from the base of plants on the respective plots collected on August 17, August 24, September 3, September 11, and September 19. These percentage values are of

TABLE I—PLOT NUMBERS, TREATMENTS, YIELDS, PERCENTAGES OF N, P_2O_5, K_2O, CAO, AND MGO IN THE FIRST LEAF FROM THE BASE, TOGETHER WITH THE DERIVED FOLIAR DIAGNOSIS VALUES (DATA REPRESENT MEAN VALUES FROM FIVE PERIODIC SAMPLINGS)

Tier	Plot	Amount 4–16–4 Fertilizer Per Acre (Lb)	Yields Green Pods Per Plot (Lb)	N (Per Cent)	P_2O_5 (Per Cent)	K_2O (Per Cent)	CaO (Per Cent)	MgO (Per Cent)	Intensity $N+P_2O_5+K_2O$ (Per Cent)	Composition of NPK-Units
Irrigated Plots										
2	9	667	39.9	2.46	0.67	3.73	7.28	1.05	6.86	61.29:10.48:28.23
2	10	333	33.7	2.46	0.59	3.37	7.07	1.24	6.40	63.66: 9.44:26.90
2	12	167	27.0	2.40	0.60	3.05	6.82	1.08	6.05	64.69:10.15:25.16
2	11	0	25.7	2.40	0.60	2.86	7.45	0.89	5.86	65.52:10.36:24.12
Non-Irrigated Plots										
1	14	667	23.7	3.15	0.61	2.52	7.38	1.35	6.28	73.39: 8.66:17.95
1	11	0	22.8	2.77	0.48	2.54	6.49	1.27	5.79	72.04: 7.71:20.25
1	13	333	17.4	2.94	0.54	2.11	7.97	1.53	5.59	75.19: 8.22:16.60
1	12	167	15.4	2.75	0.53	2.14	7.04	1.09	5.42	73.94: 8.69:17.37

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interest because they afford a comparison of the effects of irrigation on the mineral composition of plants under the conditions of these experiments with those of Greaves and Carter (1) who report a decrease in nitrogen and a progressive increase in P_2O_5, K_2O, CaO, and MgO in wheat, oats and barley as the water used in irrigation is increased.

The values for nitrogen in column 5 of Table I show that in this experiment also the nitrogen content has decreased with irrigation and the decrease is greater the higher the application of fertilizer. The data of columns 6 to 9 show that the content of P_2O_5 and K_2O has increased under irrigation as in Greaves and Carter's experiments; but that with the exception of CaO in the check (nothing) plots, the content of CaO and MgO has decreased under irrigation. Because of the marked effect of irrigation on the K_2O content, the sum of the ash constituents ($K_2O + P_2O_5 + CaO + MgO$), however, is greater under irrigation.

YIELDS AND THE RELATIONSHIP OF FOLIAR DIAGNOSIS VALUES

The derived foliar diagnosis values of the intensities of nutrition and the composition of the NPK-units (2, 4) are shown in columns 10 and 11 respectively, and graphically in Fig. 1. The yields of all the irrigated plots are greater than those of the unirrigated plots, the highest yielding plot from the unirrigated tier being lower than the lowest yielding plot on the irrigated tier. In the irrigated tier the yield of the unfertilized plot is lowest, after which yields progressively increase with increase in the level of fertilizer application. Although the highest yielding plot in the unirrigated tier is that which received the highest application of fertilizer, the lowest yield is given not by unfertilized plot, but by the plot which received the lowest application of fertilizer. Among the fertilized plots, nevertheless, yields progressively increase with the increase in level of fertilizer application. Because the unfertilized plot is second highest in yield among the unirrigated plots, it would be impossible to rationalize with respect to the effect of the fertilizer from yields on the unirrigated tier. As will be pointed out later, an explanation of the paradox is afforded by the differences in nutrition of the plants as placed in evidence by their foliar diagnosis values. In both irrigated and unirrigated tiers, yields are related to the intensities of nutrition in such a way that the greater the intensity the higher is the yield. The intensity of nutrition of the leaves from plants growing on the unirrigated tier receiving the highest application of fertilizer (No. 1–14), however, is higher than that from plants on the unfertilized, irrigated plot (No. 2–11) as well as that from the irrigated plot which received the lowest application of fertilizer, (No. 2–12). The effect of a fertilizer, however, is not measured solely by the effect on the intensity of nutrition. The physiological relation among the elements also must be taken into consideration (3, 5).

Although the intensity of nutrition of plot No. 14 is relatively high, lack of balance is indicated by the poor equilibrium compared with that of the optimum. In Fig. 1 this is shown by the much greater displacement of the locus of the *NPK-unit* of No. 1–14 from the position of the optimum (No. 2–9) compared with those of plots Nos. 2–11 and 2–12. Intensity alone, therefore, is insufficient for high yields if the equilibrium is poor.

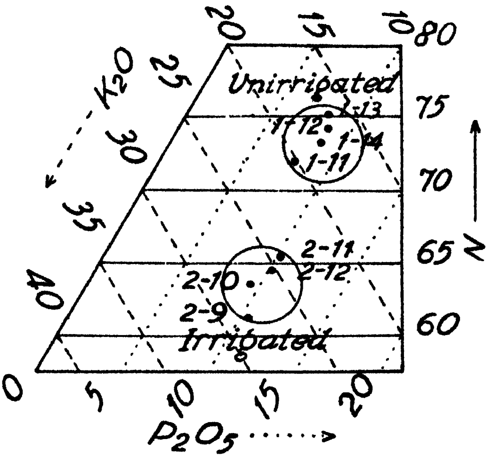

FIG. 1. Mean NPK-units of leaves from bean plants grown on the different irrigated and unirrigated plots, represented in trilinear coordinates. Only a portion of the triangle, of which each side equals 100, is shown.

The nutrition of plants growing on the optimum yielding plot (No. 2–9), which received the highest level of fertilizer under irrigation, is characterized by the highest values for K_2O and P_2O_5 in the composition of the *NPK-unit* and with the lowest value for N of any of the plots. The next highest yielding plot (No. 2–10), the irrigated plot which received the second highest application of fertilizer, is nearest the locus of the optimum and has the second highest value for the intensity. This is followed in order of yields and position of the loci of *NPK-units* and of intensities by plants from plots No. 2–12 and 2–11, the irrigated plots receiving the lowest level of fertilizer application and no fertilizer, respectively.

The loci of the low yielding, unirrigated plots are relatively far removed from the locus of the optimum and are, moreover, sharply segregated from the loci of all irrigated plots. The nutrition of the low yielding unirrigated plots is characterized by relatively low values for P_2O_5 and K_2O in the composition of the *NPK-unit* and high values for N. In the unirrigated plots, the order of yields is not regularly related to the positions of the loci of their *NPK-units*, although, as already stated, the yields follow the same order as the values for the intensities of nutrition. From a detailed examination of the course of nutrition (2, 4 page 5) which space limitations of this paper prevent, it can be shown that this irregularity is the result of irregularities of the soil with respect to potash, which have been swamped by irrigation especially in the plots receiving high applications of fertilizer.

INFORMATION GIVEN FROM THE DATA OF THE EARLIEST SAMPLING

From the standpoint of conservation of time, it is always of interest to know the kind of information that may be furnished from the first, the earliest, sampling. The data for the first samples collected on August 17, 22 days after planting, are shown in Table II and presented graphically in Fig. 2. A comparison of Fig. 2 with Fig. 1 reveals that sharp separation of the loci of the *NPK-units* of the irrigated and unirrigated plots occurs also in these first samples. As in Fig. 1 the

TABLE II—THE RELATIONSHIP OF FOLIAR DIAGNOSIS VALUES TO YIELDS AT THE EARLIEST SAMPLING

Tier	Plot	Amount 4-16-4 Fertilizer Per Acre (Lb)	Yields Green Pods Per Plot (Lb)	N (Per Cent)	P_2O_5 (Per Cent)	K_2O (Per Cent)	Intensity $N+P_2O_5+K_2O$ (Per Cent)	Composition of NPK-Units
				Irrigated Plots				
2	9	667	39.9	3.79	0.81	4.53	9.13	67.45:8.47:24.08
2	10	333	33.7	3.68	0.70	3.86	8.24	70.16:7.91:21.94
2	12	167	27.0	3.80	0.72	4.25	8.77	69.15:7.80:23.05
2	11	0	25.7	3.75	0.70	3.84	8.29	70.60:7.85:21.55
				Non-Irrigated Plots				
1	14	667	23.7	4.79	0.78	3.26	8.83	76.97:7.42:15.61
1	11	0	22.8	4.06	0.49	2.87	7.42	77.98:5.60:16.42
1	13	333	17.4	4.54	0.62	2.33	7.49	81.02:6.60:12.38
1	12	167	15.4	4.15	0.65	2.85	7.65	77.05:7.17:15.78

loci of the *NPK-units* of leaves from plants on the irrigated tier from this first collection are further from the summit apex (N = 100) and nearer the left-base apex (K_2O = 100) and also the right base apex (P_2O_5 = 100) than are those from the unirrigated tier, indicating lower N and higher K_2O and P_2O_5 in the composition of the *NPK-units.*

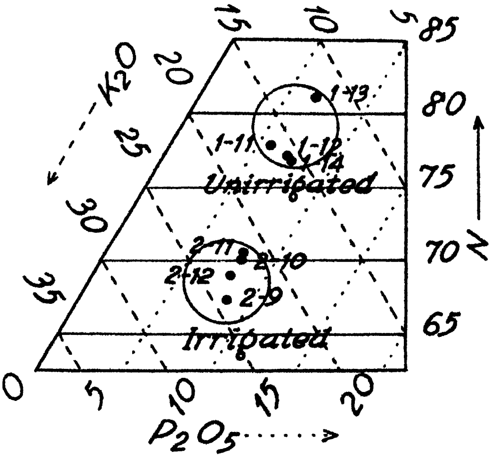

FIG. 2. NPK-units of leaves at the first sampling date from bean plants grown on the different irrigated and unirrigated plots, represented in trilinear coordinates. Only a portion of the triangle, of which each side equals 100, is shown.

In the younger leaves of the first collection, however, the loci of the respective plots are displaced higher up towards the summit apex and farther from the right and left base apices than are those from all collections, indicating higher N and lower K_2O and P_2O_5 in the composition of the *NPK-units* than is given by the resultant from all five samplings. Moreover, the characteristics that distinguish the optimum yielding plot, No. 2–9, based on the resultant values of all five samplings, are distinctive at the first collection. Thus, the intensity of nutrition of the leaves from this optimum yielding plot is highest at this earliest date of sampling and the locus of the *NPK-unit* of the leaves from this plot is displaced further from the summit apex and nearer to the left and right base apices than are any of the others.

The intensitites of nutrition at the first sampling dates, however, do not show so close a relationship to yields as when all samplings are considered.

Thus, by the analysis of a few leaves, and therefore, without destroying the experiment, the method of foliar diagnosis gives valuable information to the field experimenter concerning the nutrition of his plants. In fact, the values for foliar diagnosis can be a more accurate index of the effect of a fertilizer than are the yields. If, for example, the stand is irregular, the nutrition of the plants, as placed in evidence by the values for foliar diagnosis, would give a more accurate evaluation of the effect of the factors varied than would the yields.

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Quality in the Chantenay Carrot and its Relation to Seed Production

By N. K. Ellis, *Purdue University, Lafayette, Ind.*

THE Chantenay carrot is most commonly used by canners in Indiana. It was observed that seed from the same reliable seedsman would produce a crop of high quality roots one season, and of low quality, with many roots light yellow in color and flat to the taste, the next. In addition, considerable variation occurred between roots of the same seeding. A method was desired whereby individual roots could be rated for quality before being planted for seed production.

The procedure finally adapted consisted of three steps. (a) Roots were selected for typical Chantenay shape and uniform length, 4½ to 5½ inches long. (b) Roots were selected for color, first on the outside appearance and second by cutting about 1½ inches from the bottom of each carrot. If this cross-section did not show a red core, the root was discarded before the final step. (c) The portion cut from the root was then diced and its juice expressed under 8,000 pounds of pressure per square inch in a Carver hydraulic press. The refractive index of the expressed juice was then determined. The cut portion of the root was then sealed over with paraffin to protect it in storage. Vegetable wax has also been used.

It was found that the refractive index might be used to express a figure for quality since the higher the index the sweeter the carrot is to the taste. A numerical value can therefore be put on taste. It is admitted that other things than sugars may be included in the measurement of total solids, but for simplicity, the translation table to sucrose was used to express a working figure for quality.

From the 1939 crop of Red Cored Chantenay, 46 roots were selected for size and color. All of these roots were therefore of equal value for seed stock as far as could be judged visibly. Table I shows the range of quality found. All carrots below 10 per cent were flat to the taste, those in the 10 to 11.9 per cent range were of fair quality, and the flavor of those above 12 per cent was excellent. The range was from 5.3 to 14.5 per cent. Table I also shows the distribution of carrots from a seedsman's special strain of Chantenay which was grown on mineral soil. In this excellent lot, the same quality range persisted,

TABLE I—Range of Quality in Chantenay Carrot as Measured by Soluble Solids Expressed as Per Cent Sucrose

Range of Refractive Index*	Soluble Solids Expressed as Per Cent Sucrose	Distribution of Carrots from 1939 Crop Red Cored Chantenay Grown on Muck	Distribution of Carrots from Special Strain Chantenay Grown on Mineral Soil 1941
1.3403–1.3447	5– 7.9	6	—
1.3448–1.3477	8– 9.9	14	3
1.3479–1.3508	10–11.9	21	10
1.3510–1.3590	12–17	5	14

*Temperature, 20 degrees C.

TABLE II—RANGE OF QUALITY OF FOUR STRAINS OF CHANTENAY FROM THE 1940 CROP GROWN ON MUCK SOIL

Determination Number	Greater Chantenay (Per Cent Sucrose)	Oregon Chantenay (Per Cent Sucrose)	Improved Chantenay (Per Cent Sucrose)	Red Cored Chantenay (Per Cent Sucrose)
1	10.9	10.8	11.3	10.6
2	10.9	10.8	12.8	10.9
3	11.2	11.3	12.8	11.0
4	11.5	11.6	13.0	11.6
5	11.8	12.7	13.4	11.6
6	11.9	12.7	13.4	11.6
7	12.2	13.7	13.5	11.6
8	12.5	14.0	14.7	11.9
9	13.0	17.0	14.8	12.5
10	15.5	17.3	14.8	12.7
Average	12.14	13.10	13.45	11.6

and only three carrots were discarded as undesirable to the taste.

Table II shows four of the strains of Chantenay carrots grown in 1940. The quality was relatively good for all carrots tested, however, the table shows the variation which occurs between strains. The average of the determinations indicates the general quality, but is of little use without the individual determinations to show the range which in itself indicates uniformity in the strain; for example, 10. Improved Chantenay had an average of 13.45 per cent and a narrow range of 11.3 to 14.8 per cent between roots, while Oregon Chantenay had an average of 13.19 per cent and a range from 10.8 to 17.3 per cent, which indicated that the strain was much more variable.

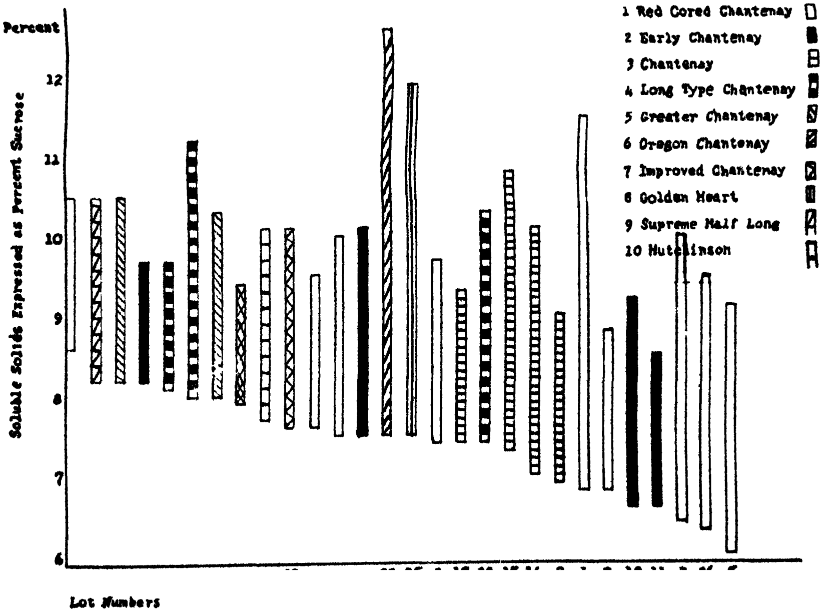

FIG. 1. Variation in quality of 28 strains of carrots. The bars represent the distribution of values from five consecutive samples from each of the 28 strains.

Fig. 1 shows the range of quality from five consecutive carrots from 28 lots of carrot seed. It will be observed that there is a wide variation between seed lots and between the roots within the same lot. Lots 1, 5, 7, 20, 25, and 26 are not uniform in quality. The most uniform seed lots are shown by the shorter bars in the higher per cent quality such as lots 10, 18, 21, 28, and 29. Lots 1 to 7, 26 and 28 were Red Cored Chantenay. All lots of seed were purchased from retail seedsmen, but all varieties were not true to type. Lots 8, 14, 15, and 17 were Chantenay. Lots 9, 10, 11, and 12 were Early Chantenay, 16 was Special Chantenay, 18, 19, and 25 were Greater Chantenay, 20 was Oregon Chantenay, 21 and 22 were Long Type Chantenay. Included in the trial were three other strains and varieties, No. 23 was Red Heart, No. 24 Hutchison, and No. 29 was Supreme Half Long.

When an attempt was made to grow seed from roots selected from the 1939 crop, it was observed that most of the roots which had shown high quality, rotted in the field and failed to produce seed. In 1941, counts were made on roots planted in the field for seed production. The trial was not originally designed as a test of the vitality of planting stocks, but the counts may aid in determining why seed stocks vary from year to year. Roots were planted which had shown a quality number of 10 to 14 per cent. Since these roots were for seed production, no roots were planted below the 10 per cent level. Sixty-three per cent of the lot having a quality number of 10 per cent survived; 30 per cent of the number 11 lot survived, 15 per cent of the number 12 lot, 16 per cent of the number 13 lot and 11 per cent of the number 14 lot grew and produced seed. It is expected that these figures will vary with the season, and in favorable seasons the proportion of the better quality roots that survive will be greater and will therefore produce a better grade of seed. It may be inversely true that in bad seasons, the chances of the better quality roots producing seed will be less and that through no fault of the seedsman, he will be unable to furnish high quality, uniform seed.

An Experimental Mechanism for the Band-Placing of Fertilizer in Irrigated Beds[1]

By A. E. GRIFFITHS, *Arizona Agricultural Experiment Station, Tucson, Ariz.*

THE past five years has witnessed a general change from the broadcast to the band-placement method of fertilizing lettuce in Arizona. The latter method has proved to be efficient and economical, but has emphasized the need for an accurate control of rate of application. Since the fertilizer band is often placed within 3 inches of the seed row, variations in the amount applied, or in the distance of the ribbon from the row, may result in severe burning of the seedling plants. Also in nutritional experiments involving the band-placement of fertilizer, it is important that a high degree of control of rate of application be obtained. Even slight variations in the rate have resulted in erroneous data.

The gravity-feed fertilizer hopper has certain disadvantages especially in experimental usage: (a) rates of application must be determined by trial; (b) rate of delivery varies slightly as the hopper empties; and, (c) light, or "fluffy" and moist fertilizers tend to settle unevenly, resulting in uneven flow. In order to overcome these objections and to increase control of error, a revolving-cylinder, top-delivery hopper was installed on an experimental single-bed lettuce sled in 1941. Numerous data were taken on the performance of the machine, and are herein reported.

In Arizona, as in most southwestern irrigated districts, lettuce is sown in two rows, 12 to 18 inches apart, on raised beds 36 to 42 inches wide and usually from 600 to 1200 feet long. In commercial practice the field is furrowed out by means of shovel plows or listers. The fertilizer is banded into both sides of the bed from hoppers and shoes mounted on the tractor. This method of fertilizer application, almost universal in Arizona, approaches true band-placement, in that the fertilizer is concentrated in a ribbon approximately 4 inches above the center of the furrow and about 3 inches deep. However, it has the major disadvantage of resulting in variable distances between ribbon and seed row.

After the beds are thrown up, the seed is planted by means of standard seed planter units mounted on a sled. The sled usually consists of three runners on which are mounted metal shapers and packers as well as six to eight seed units. Power for the seed units is obtained from one or more ground wheels.

In order to overcome errors introduced by band-placing the fertilizer and by planting the seed separately, Dr. W. A. Frazier of the Arizona Agricultural Experiment Station designed a single-bed experimental sled which mounted both fertilizer and seed units, and provided for the application of the fertilizer and the drilling of the seed in a single operation.

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[1] Appreciation is extended to members of the Bureau of Agricultural Chemistry and Engineering of the United States Department of Agriculture for their aid in obtaining and calibrating the fertilizer hoppers used in this work.

The original sled was built in 1938. During the summer of 1941 the gravity-feed fertilizer hoppers, which were a part of the original equipment, were replaced by a single center-mounted revolving-cylinder, top-delivery hopper[2] and the power transmission system redesigned.

The sled is 102 inches long by 40 inches wide. Each runner has three V-shaped, steel-shod, shaper blocks which are 4 inches wide at the bottom and 12 inches wide at the top. The shaper blocks pack the sides of the bed and leave a firm, well-shaped furrow. In addition to the shaper blocks the sled is equipped with adjustable steel plates for shaping the top of the bed. One set of these is mounted at the front of the sled to shape the bed ahead of the fertilizer shoes. The second set of shaper plates is mounted behind the fertilizer units and in front of the seed units. This set reshapes and smooths the bed for the seed. Both sets of plates may be adjusted to leave a crown or flat-topped bed with a vertical rise from the bottom of the furrow of 6 to 10 inches.

The seed units are mounted individually at the rear of the sled on a horizontal rod and may be adjusted laterally to give a row spacing of 12 to 18 inches.

The fertilizer hopper is permanently mounted in the center of the sled (Fig. 1). The feeder tubes drop vertically to the applicator shoes. The shoes are mounted on individual frames, one on each side of the bed. The frames are mounted on a horizontal bar at the front of the sled, allowing complete lateral adjustment. The shoes may be vertically adjusted to give any depth of application desired, and the entire unit

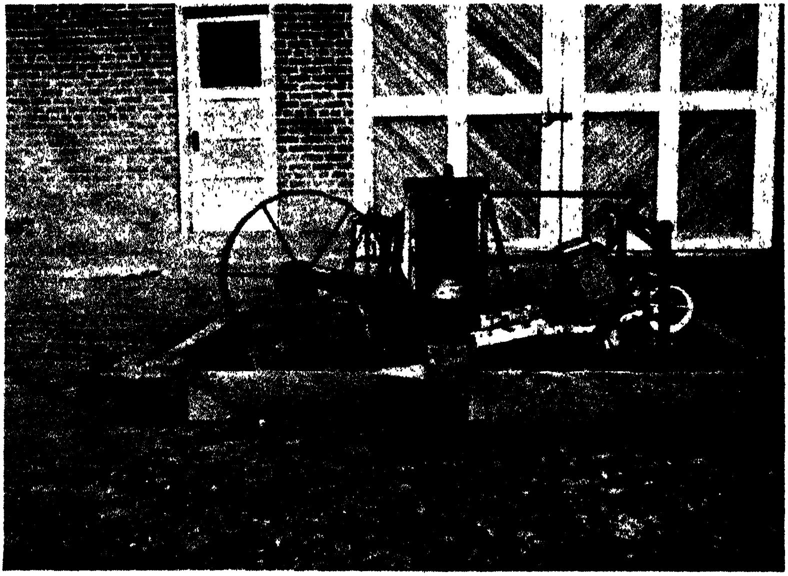

FIG. 1. Lettuce fertilizer and planter sled. Top-delivery hopper

of frame and shoe is so balanced, that when the sled is in motion, the shoe travels at the set depth.

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[2] Purchased from the Cole Manufacturing Company.

The fertilizer hopper is powered by a 28-inch ground wheel with a 4-inch tread. The wheel travels on the top of the bed and is joined to the frame of the hopper so that complete freedom of vertical movement is possible. Power is transmitted to the hopper by chain drive through sprockets mounted on a counter shaft (Fig. 2), and then to a sprocket mounted on the hopper pinion shaft. The power shaft mounts an 18-point sprocket which is never changed. The counter shaft and pinion shaft mount three sprockets which are easily slipped on and off. Varying the ratio between these three sprockets changes the rate of fertilizer applied per acre.

FIG. 2. Power, counter, and pinion shafts with chain transmission.

When the sprocket ratio has been properly determined, the hopper will revolve in a definite proportion to the number of ground wheel revolutions over a given distance. The bottom of the hopper will rise a definite amount for every revolution of the ground wheel. The fertilizer level in the hopper is thus raised at a constant rate, and the fertilizer is removed and directed down the tubes by scraper blades (Fig. 3).

Charts and instructions have been prepared by the Bureau of Agricultural Engineering, United States Department of Agriculture for the calculation of the sprocket ratios for different rates of fertilizer application.

Briefly, the following points must be known in order to calculate the ratio for a desired application: (a) the number of revolutions of the ground wheel per 1/100 acres or other known distance; (b) the number of hopper revolutions required to deliver the total amount of

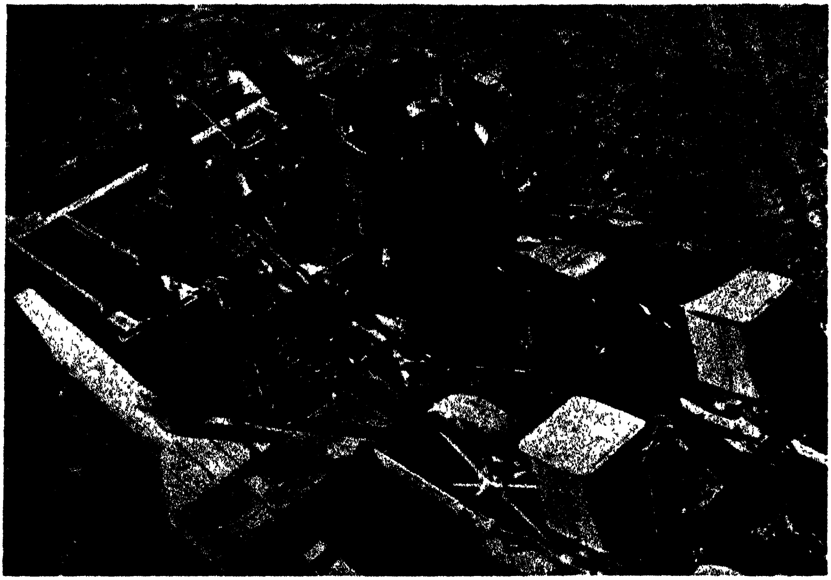

FIG. 3. Hopper showing split nut and scraper plates.

fertilizer held by the hopper (80 revolutions are required for the 10 inch by 16 inch hopper); (c) the desired application per acre; and, (d) the weight of a given fertilizer held by the hopper. The use of a container the exact size of the hopper facilitates this.

When the foregoing factors are known, simple arithmetical calculations will give the number of hopper revolutions per 100 revolutions of the drive wheel needed to deliver a given amount per acre of a specific fertilizer. This factor is used to enter the previously described charts, from which is obtained the proper sprocket ratio. When the ratio has been determined for a given application of a specific fertilizer, simple proportion will determine the correct sprocket ratio for different rates of application.

RESULTS

There are two possible sources of error involved in the use of the top-delivery hopper. These are: (a) slippage of the ground wheel; and (b) failure to properly settle the fertilizer in the hopper.

Slippage of the ground wheel was the first source of error to be investigated in connection with the use of the top-delivery hopper on the lettuce sled. In Table I is listed the constants of the ground wheel. It will be noted that theoretically the wheel should make 17.8 revolutions in 130.7 linear feet, which is equivalent to 1/100 acres based on a standard 40 inch lettuce bed. It was recognized that soils of different texture and degree of moisture content would cause some variation in the slippage of the ground wheel. The revolutions of the wheel were counted five times in each of twenty different locations. The soil

TABLE I—THE SLIPPAGE FACTORS OF THE GROUND WHEEL SUPPLYING POWER TO THE SEED MOUNTED TOP-DELIVERY FERTILIZER HOPPER

Diameter of power wheel	28 inches
Circumference of power wheel	88 inches
Width of tread	4 inches
Weight of wheel	10 pounds
Calculated revolutions per 1/100 acre*	17.8 revolution
Actual revolutions per 1/100 acre (mean of 20 determinations)	16.2 revolution
Mean slippage	1.6 revolution
Standard deviation of a single determination	±0.2 revolution
Standard deviation of the mean actual revolution	±0.05 revolution

*1/100 acre is equivalent to 130.7 linear feet of the standard 40-inch lettuce bed.

condition varied from moist to dry; fine to cloddy; and heavy clay to sandy loam. Three fertilizers were used varying in texture from powdered to powder-and-pellet mixtures. Rates of application were from 150 to 350 pounds per acre.

Table I shows that the mean actual revolutions of the ground wheel per 1/100 acre was 16.2 ± .05 revolutions. This was a mean slippage of 1.6 revolutions per 1/100 acre. The standard deviation of any single determination is ± .2 revolutions. On the basis of these data it was considered justifiable to adopt 16.2 revolutions per 1/100 acre, or 1620 revolutions per acre (based on a 40 inch bed) as the ground wheel constant.

Table II gives the percentage error from the desired amounts, of actual pounds of fertilizer applied per acre. Eleven fertilizers applied at 13 different rates were studied. In all 85 determinations were made under several soil conditions. The mean error, calculated from the desired amount, is 3.6 per cent ± .3 per cent. The error of a single determination is ± 2.9 per cent.

Errors as great as 15 per cent have been recorded for the gravity

TABLE II—A DETERMINATION OF THE DEGREE OF ACCURACY OBTAINED IN APPLYING FERTILIZER WITH THE TOP-DELIVERY HOPPER

Kind of Fertilizer	No. of Tests	Desired Rate Per Acre (Lbs)	Mean Actual Rate Per Acre (Lbs)	Mean Error* (Per Cent)
Ammonium sulfate	7	200	201.7	2.6
Ammonium sulfate	4	140	133.5	4.7
Ammonium sulfate	1	80	81.0	1.3
Treble superphosphate	4	270	271.3	4.8
Treble superphosphate	7	200	199.6	2.9
Treble superphosphate	3	160	160.3	3.5
Ammonium sulfate + treble superphosphate	1	240	241.0	0.4
Ammonium sulfate + calcium metaphosphate	3	190	196.6	7.7
Sodium nitrate	4	180	185.8	3.2
Calcium nitrate	3	100	100.7	4.7
16–20 (Ammophos)	7	250	238.3	5.7
11–48 (Ammophos)	4	255	251.5	1.8
11–48 (Ammophos)	8	200	196.5	5.0
11–48 (Ammophos)	17	150	148.8	3.1
11–48 + potassium sulfate	3	355	344.3	5.1
11–22 (commercial mix)	6	255	256.3	2.9
7–28 (experimental mix)	3	250	230.0	8.0
Total tests	85			
Average mean error, all tests				3.6 per cent
Standard deviation of a single determination				±2.9 per cent
Standard deviation of the average mean error				±0.3 per cent

*Calculated from the errors of the individual determinations.

feed hopper in experimental work. The top-delivery hopper in a single series of tests has given average errors of 4 per cent or less.

In a statistical break-down of the data described in this paper, no significant differences have been found in the accuracy of application of fertilizers of different textures. It is true that commercial and experimental mixtures containing considerable quantities of organic bases, such as bloodmeal and finely divided goat-manure, tend to be distributed less accurately than simple, powdered, inorganic fertilizers. The average error of distribution of powdered fertilizers was 2.8 per cent ± .9 per cent, while that of mixtures and pelleted forms was 4.7 per cent ± .9 per cent.

Relation of Fertility Levels and Temperature to the Color and Quality of Garden Beets

By ROBERT BLACKMORE, FLORENCE NEUMAN, HOWARD D. BROWN, and ROBIN C. BURRELL, *Ohio State University, Columbus, Ohio*[1]

DETROIT Dark Red beets grown during the 1940 and 1941 seasons on the Ohio State University fertilizer plots at Columbus, Ohio showed noticeable color variations. The treatment of the plots for the past 12 years are as follows:

Checks 1 and 9—No fertilizer except green cover crop
Complete—1000 pounds per acre of 8–20–12
–N—1000 pounds per acre of 0–20–12
2N—1000 pounds per acre of 16–20–12
–P—1000 pounds per acre of 8– 0–12
2P—1000 pounds per acre of 8–40–12
–K—1000 pounds per acre of 8–20– 0
2K—1000 pounds per acre of 8–20–24

Rye is planted on all plots each year to help conserve the organic

TABLE I—CHEMICAL ANALYSIS OF THE HYPOCOTYLS AND ROOTS OF DETROIT DARK RED BEETS GROWN AT COLUMBUS, OHIO (HARVESTED JUNE 27, 1941, ALL DATA IN GRAMS)

Material	Fertilizer Treatments								
	Check 1 0-0-0	Check 9 0-0-0	Complete 8-20-12	-N 0-20-12	2 N 16-20-12	-P 8-0-12	2 P 8-40-12	-K 8-20-0	2 K 8-20-24
Fresh weight	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Dried weight	13 59	13.60	13.54	13.62	13.58	13.59	13.55	13.60	13.58
Alcohol insoluble extract dried weight	3.905	3.920	3.375	3.955	3.310	3.685	3.315	3.835	3.620
Total ash..	0.700	0.724	0.935	0.972	1.182	1.081	1.266	0.755	1.228
Alcohol soluble extract dried weight	8.326	8 534	8.644	9.633	8.506	9.700	8.325	8.493	8.149
Total soluble nitrogen. .	0.0860	0.0952	0.1502	0.0866	0.1631	0.1340	0.1429	0.1080	0.1075
Soluble nitrate nitrogen.	0.0025	0.0028	0.0100	0.0040	0 0145	0.0065	0.0091	0.0075	0.0089
Soluble ammonia nitrogen . . .	0.0035	0.0048	0.0121	0.0082	0.0154	0.0074	0.0086	0.0070	0.0102
Soluble amide nitrogen .	0.0061	0.0042	0.0059	0.0030	0.0130	0.0084	0.0140	0.0133	0.0120
Insoluble nitrogen . . .	0.1835	0.1837	0.1901	0.1816	0.2074	0.1973	0.1944	0.1927	0.1830
Soluble reducing sugars .	0.633	0.654	0.861	0.615	0.396	0.613	0.381	0.464	0.324
Soluble total sugars.....	4.881	5.022	3.695	5.251	3.489	4.433	4.844	4.454	2.636
Starch......	0.0521	0.0556	0.0800	0.0528	0.0559	0.0609	0.0560	0.0649	0.0492
Phosphorus..	0.0350	0.0363	0.0385	0.0397	0.0397	0.0353	0.0425	0.0396	0.0399
Potassium...	0.1443	0.1374	0.2794	0.2285	0.2648	0.1969	0.2210	0.1539	0.2845
Calcium	0.0286	0.0254	0.0230	0.0303	0.0247	0.0299	0.0248	0.0295	0.0198
Crude fiber..	0.895	0.892	1.222	0.951	0.911	0.989	1.200	1.267	0.963

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[1] Assistance in the preparation of these materials was furnished by the personnel of Works Progress Administration Official Project No. 65–1–42.89.

matter content of the soil. Planting dates for beets in 1941 were April 15, June 10, and July 20.

Chemical analyses of the hypocotyls and roots (called roots in this experiment) of Detroit Dark Red beets harvested June 27 are given in Table I. Briefly these analyses show: (a) total soluble and insoluble nitrogen was found to be highest in the roots grown on the double nitrogen plot; (b) total sugars were found to be greatest in the roots grown on the check and minus nitrogen plots; (c) phosphorus was found highest in the roots grown on the double phosphorus plot; (d) potassium was found greatest in the roots grown on the double potassium plot, the addition of nitrogen, phosphorus and a complete fertilizer increased the potassium content; (e) calcium content of the roots was found to be high in all the minus and check plots, large applications of potash depressed the calcium intake; and (f) crude fiber of the roots was the highest in the minus potassium plot, also high in the plots receiving double phosphorus and complete fertilizers.

The color of the beets varied much throughout the growing season. Early in the season the average beet color was much lighter than the color later in the fall. Tables II and III show this as well as the effects of high temperature on beets with an abundant foliage. During the last week in July and the first week of August, the temperature was above average (mean temperature 80 to 90 degrees F). At this period

TABLE II—MEAN COLOR INDICES OF FIVE TYPICAL DETROIT DARK RED BEETS AT COLUMBUS, OHIO (PLANTED APRIL 15, 1941)

Date Harvested	Fertilizer Treatments								
	Check 1 0–0–0	Check 9 0–0–0	Complete 8–20–12	–N 0–20–12	2 N 16–20–12	–P 8–0–12	2 P 8–40–12	–K 8–20–0	2 K 8–20–24
Jul 7...	2.8*	3.0	3.2	2.8	3.2	3.0	3.2	3.2	3.2
Jul 14..	3.0	3.0	3.2	3.2	3.4	3.0	3.6	3.4	3.4
Jul 21..	3.2	3.2	3.4	3.4	3.4	3.2	3.6	3.4	3.4
Jul 28..	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.2
Aug 5..	3.6	3.6	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Aug 14.	3.6	3.6	3.6	3.6	3.6	3.6	3.8	3.6	3.6
Aug 21.	3.6	3.8	4.0	3.8	4.0	3.6	4.2	3.8	3.8

*1, Pink and orange; 2, pink red faint orange; 3, pink red to red; 4, red and purple; and 5, purple

TABLE III—MEAN INDICES OF RINGS OF FIVE TYPICAL DETROIT DARK RED BEETS AT COLUMBUS, OHIO (PLANTED APRIL 15, 1941)

Date Harvested	Fertilizer Treatments								
	Check 1 0–0–0	Check 9 0–0–0	Complete 8–20–12	–N 0–20–12	2 N 16–20–12	–P 8–0–12	2 P 8–40–12	–K 8–20–0	2 K 8–20–24
Jul 7 ..	3.0*	3.2	3.0	3.0	3.0	3.2	3.0	3.0	3.0
Jul 14..	3.2	3.4	2.8	3.0	2.8	3.2	3.0	3.0	3.0
Jul 21..	3.2	3.0	2.6	2.8	2.6	3.0	2.4	2.8	2.6
Jul 28..	2.6	2.6	2.4	2.6	2.4	2.6	2.4	2.4	2.4
Aug 5	2.4	2.4	2.4	2.4	2.4	2.2	2.6	2.2	2.4
Aug 14.	2.0	2.2	2.0	2.2	2.0	2.2	2.0	2.2	2.2
Aug 21.	2.2	2.0	1.8	2.2	1.8	2.2	1.6	2.0	2.0

*1, No rings and color uniform; 2, no white rings all color rings; 3, white rings faint, most colored rings; 4, white rings equal colored rings; and 5, all rings white.

the color of the beets, ordinarily those darkest in color (grown on plots receiving complete and double applications of fertilizer) became light red in color. We believe these reversals were caused by a higher respiration rate on those beets with greater foliage, resulting in a breakdown of the pigments. A laboratory experiment was then set up to see if similar color changes could be produced by harvesting field grown beets and storing them in a laboratory at 70 to 75 degrees F. The best leaves were wrapped in parchment paper and kept moist. A check included a beet plant with unwrapped leaves moistened by daily applications of water. After 3 weeks of this treatment all tops were examined. The unwrapped beet tops were the first to die. The unwrapped beets showed no appreciable changes in color. The wrapped beets, in about 50 per cent of the cases became lighter in color; in some extreme cases almost white in color. From field and laboratory observations it is concluded that this breakdown of anthocyanin pigments is due to high temperatures associated with abundant foliage. A decrease in temperature results in an increase of anthocyanin pigments in beets.

Taste tests of beets grown under each fertilizer treatment (cooked 15 minutes in boiling distilled water) varied consistently throughout the tasting period. Beets grown on the check and minus nitrogen plots had a strong sweet first taste which was followed by a very bitter after

TABLE IV—TOP-ROOT WEIGHTS OF FIVE TYPICAL DETROIT DARK RED BEETS AT COLUMBUS, OHIO (PLANTED JUNE 10, 1941, ALL DATA IN GRAMS)

	Fertilizer Treatment								
	Check 1 0-0-0	Check 9 0-0-0	Complete 8-20-12	-N 0-20-12	2 N 16-20-12	-P 8-0-12	2 P 8-40-12	-K 8-20-0	2 K 8-20-24
Date Harvested—Aug 18									
Tops...	266.0	322.5	351.5	268.5	371.0	291.0	444.0	382.5	233.0
Roots* .	215.0	317.0	280.0	250.0	270.0	243.0	340.0	310.0	251.0
Date Harvested—Aug 26									
Tops...	291.0	292.0	513.0	265.0	391.0	505.0	424.5	398.0	334.0
Roots ..	325.0	355.0	572.0	294.0	345.5	496.0	413.0	658.0	491.0
Date Harvested—Sep 3									
Tops...	147.5	288.0	430.0	252.0	451.5	246.0	440.0	315.0	374.0
Roots ..	233.58	320.0	632.0	306.0	545.0	445.5	807.0	364.0	491.0
Date Harvested—Sep 13†									
Tops...	286.5	226.5	548.5	505.5	611.5	269.5	500.0	384.0	592.5
Roots ..	928.5	832.5	1249.5	1238.0	1525.0	1074.0	1472.0	1266.5	1483.5
Date Harvested—Sep 23									
Tops...	94.5	109.0	238.0	160.0	276.5	144.0	147.0	163.0	206.0
Roots ..	471.5	588.0	760.0	511.0	996.5	406.0	939.5	834.0	892.0
Date Harvested—Oct 1									
Tops...	93.5	210.0	329.0	148.0	443.0	166.0	313.0	257.0	444.0
Roots ..	347.0	1101.5	1665.0	746.5	1466.0	908.0	1786.0	1044.0	1595.0
Date Harvested—Oct 11									
Tops...	69.0	197.5	469.0	156.0	503.5	235.5	425.0	272.0	625.5
Roots ..	284.5	954.0	1713.0	678.0	1753.5	848.5	2232.0	1155.5	2018.5

*Roots mean hypocotyl and root.

†Took largest beets in plot all other samples are five beets.

taste. This may have been due to dextrose sugar. Beets grown on the minus potassium plots were the most fibrous (woody). Those beets grown on the minus phosphorus plots had little flavor and were classified as flat. Beets grown on the complete and double nitrogen plots varied from good flavor to flat, from sweet to bitter, tender to woody; no generalized statement could be made. Double phosphorus and double potassium plots generally produced the best flavored beets.

Top-root weights of five typical beets were taken at weekly intervals from June 1st to October 12, 1941. Top-root weights of the second planting, June 10, are shown in Table IV. These beets were thinned so that the plants stood 4 inches apart in the rows. Tops were relatively large during the earlier development of the beet. As the beets matured, the tops on all the check and minus plots made a smaller relative growth than on the complete and double fertilized plots. The check and minus nitrogen plants had the least foliage and smallest roots. From all plots taste tests were made on canned beets in 1940 and 1941. The same differences in taste were noted after canning as before canning. Double phosphorus produced the best color and minus phosphorus produced the poorest color. Tests of beets grown in 1940 by Mr. Charles Arnold showed very conclusive color differences. All his beets from the minus and check plots were of very light color, almost a yellow grey, while all his double and complete fertilizer treatments produced a deep red color. Environmental factors were checked carefully in 1941 and only slight differences were noted. However, the differences in general corresponded to the differences found by Mr. Arnold in 1940.

Conclusion

Early in the season, June to July, the color of Detroit Dark Red beets varied with the chemical composition of the soil. Chemical composition as well as the taste quality of the beet roots (hypocotyls and roots) varied with different fertilizer treatments. The yields of tops (leaves) were less when grown on the low fertilizer treatments. Size of beets was generally larger in complete and double fertilizer plots. Low temperatures produced more anthocyanin pigments, while high temperatures plus abundant foliage caused the breakdown of anthocyanin pigments.

Tetrachoric Correlation for Horticultural Research

By JOHN W. CRIST, *Michigan State College, East Lansing, Mich.*

THE quantitative measurement of certain characters of biological organisms, and parts of such organisms, is not, as yet, possible in research procedure. Technics for these measurements may eventually be devised and perfected for use, but at present they are not available. The want of them is felt particularly with respect to the need for the determination of concomitant variation.

Meanwhile, recourse must be taken to certain biometrical procedures for the estimation of correlation with measurements which are mostly, or even entirely, qualitative in kind. Two such procedures (bi-serial "r" and correlation from ranks) have been presented successively in the proceedings of this society for the past two years. The presentation of a third one, namely, tetrachoric (four-fold) correlation is now being offered for consideration.

This procedure was first devised and provided by Pearson (1). It is not new in the field of mathematics, nor unknown in certain realms of biological research, but has remained unused in the realm of horticulture, despite the possibility of its valuable employment.

It is essentially a modification of the procedure for ordinary linear correlation. Underlying it is the assumption of the Gaussian law of frequency distribution for the real, yet unattainable, quantitative values of the two varieties under observation. Demonstration will be made with data from the qualitative inspection, pairing, and grouping, of orchard-run Rome Beauty apples, taken from cold storage on July 11, 1941.

The intended test was that of the degree of association between defectiveness of the fruits (insect sting, limb-rub, russeting, shape, and so forth, combined) and their color—two characters for which, at present, there are no truly, and readily applicable, quantitative ways for measurement. The tetrachoric (four-fold) presentation of the result appears in Table I.

TABLE I—TETRACHORIC GROUPING FOR ROME BEAUTY APPLES

Characters	Poor Color	Good Color	Totals
Defective	$321^{(a)}$	$163^{(b)}$	$484^{(a+b)}$
Non-defective	$112^{(c)}$	$47^{(d)}$	$159^{(c+d)}$
Totals	$433^{(a+c)}$	$210^{(b+d)}$	643N

The simplest, but not most accurate, procedure for the discovery of "r_t" is as follows:

(1) $c+d/N = \frac{1}{2}(1-\alpha_1) =$ area under normal curve from k to ∞.

(2) $b+d/N = \frac{1}{2}(1-\alpha_2) =$ area under normal curve from h to ∞.

(3) $H = \dfrac{1}{2\pi} e^{-\frac{h^2}{2}} =$ height of normal curve at h.

(4) $K = \dfrac{1}{2\pi} e^{-\frac{k^2}{2}} =$ height of normal curve at k.

$$(5)\ hkr^2+2r=\frac{2(ad-bc)}{H\cdot K\cdot N^2}$$

Solution of equation (5) for the value of "r" gives the tetrachoric correlation (r_t).

From Table I:

$c+d/N={}^{159}/_{643}=.2473$

$b+d/N={}^{201}/_{643}=.3266$

The values for k and h, which correspond with these values for area can be readily obtained from any table that gives areas under the normal curve from — ∞ to values of "t". In this case, they are found to be respectively: 0.6830 and 0.4493.

With these values in hand, equation (3) becomes:

$$H=\frac{1}{2\pi}e^{-\frac{1}{2}(.4493)^2},$$ and equation (4) becomes:

$$K=\frac{1}{2\pi}e^{-\frac{1}{2}(.6830)^2}.$$

Solutions of these two equations (3) and (4) are not necessary. Any table which gives values for the ordinates of the normal curve for values of "t" may be used for securing them. Here, the values for H and K are respectively: 0.36058 and 0.31594.

Then, equation (5) becomes: $(.3266)(.2473)\,r^2+2\,r=$

$$\frac{2[(321)(47)]-[(163)(112)]}{(.36058)(.31594)(643^2)}$$ from which: $.08077\,r^2+2\,r=-.13456$

Solving this quadratic: $r_t=-.0675\pm.0471$

Calculation of the probable error of "r_t" is not too difficult. Closely approximate values for it can be derived through reference to Pearson's tables (2).

The coefficient ($-.0675\pm.0471$) is not significant. A sufficiently larger sample would, of course, lift it to the level of significance. However, its extremely small magnitude indicates (would, with larger sample, most probably still indicate) essentially no correlation between the defectiveness and the color of the fruits in the population which was sampled and tabulated.

Equation (5) is quadratic in kind. It involves only two of the tetrachoric functions for the values of $\frac{1}{2}(1-\alpha_1)$ and $\frac{1}{2}(1-\alpha_2)$. This gives the coefficient with an accuracy which suffices for ordinary cases and purposes. However, cases may occasionally come to hand, with the necessity for greater accuracy, even for the greatest possible accuracy.

When so, the operator can take recourse to Pearson's tables (2), page L, and make use of the fundamental tetrachoric equation:

$d/N=T_0T_0^1+T_1T_1^1r+T_2T_2^1r^2---TnTn^1r^n$, wherein

$T_0=b+d/N=\frac{1}{2}(1-\alpha_1)$ and $T_0^1=c+d/N=\frac{1}{2}(1-\alpha_2)$.

Pearson's Table (XXIX) gives the values, up to five decimal places, for tetrachoric functions up to and including the sixth one, for given values of T_0 and T_0^1. For functions beyond the sixth one the finite difference formula: $T_n = h p_n T_{n-1} - q_n T_{n-2}$, wherein $p_n = \frac{1}{\sqrt{n}}$ and $q_n = (n-2)/\sqrt{n(n-1)}$ is available for use. Furthermore, Pearson (3) gives these values (Table VII) to seven decimal places, for values of h, for the first twenty tetrachoric functions.

This procedure for the higher functions entails considerable labor. It also, especially for the condition of high correlation, leaves some uncertainty with regard to the attainment of a final result, even after having expended the effort required in the desire to reach such a result. In order to obviate, at least partially, this disadvantage, recourse can be had to Pearson (2), Table XXX, which gives corresponding values for h and k for positive values of "r_t" that range from 0.80 to 1.00. He promised a similar table for negative correlations, over this same range of their values. I am not aware that this table ever appeared and became available for use.

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Response of Cos or Romaine Lettuce to Chloropicrin Soil Treatment, Phosphate, and Lime[1]

By JOHN B. SMITH and FRANK L. HOWARD, *Rhode Island State College, Kingston, R. I.*

IN ORDER to supply information on the effect of soil fertility level on the crop yield the action of such limiting growth factors as soil acidity, phosphate levels, organic matter as manure, boron, and magnesium have been compared with chloropicrin soil treatment. Previous research of this Station (1) on the problem of the effect of the preceding crop on subsequent crops has shown that the correction of acidity by liming and the addition of large amounts of superphosphate partially overcome the growth-inhibiting effects of the previous crop. Chloropicrin soil fumigation has given us a means of determining the relative weight of the role of soil microorganisms in checking the growth of plants. These experiments were planned to bring out the interaction of these limiting factors.

MATERIALS AND METHODS

The results presented were obtained in 1939, 1940, and 1941 from Wagner pots filled with a Bridgehampton very fine sandy loam soil. This soil was taken each year from the same two plats on the Experiment Station Farm. One plat has been planted to rutabagas and the other to a cover crop of winter rye. Soil from the rutabaga plat was taken before fertilization in the spring and kept in a moist condition until placed in the cleansed Wagner pots at the start of the experiment in July. Soil from the rye plat was taken after harvest. Each year the approximate equivalent of 5,800 grams of oven-dry soil was mixed with the prescribed fertilizer materials and screened through ¼ inch mesh. Triplicate pots of soil from each plat were used for each fertility treatment. A moisture content of about 20 per cent was maintained by the addition of tap water to replace the loss of the initial weight during the growing periods. Comparison of the effects of preceding crops is not the object of this paper, and yields reported are averages from the two soils.

The basis of fertilization was 2,000,000 pounds of oven-dry soil per acre. As noted in Table I, nitrogen (N) was added at the rate of 160 pounds; phosphate (P) in various quantities, numerals are used to represent multiples of 100 pounds of P_2O_5; potash (K) at the rate of 225 pounds K_2O, and ground horse stable manure (M) at the rate of 16½ tons per acre. Three-fourths of the N was added as nitrates and one-fourth as ammonium sulfate to minimize effects on soil acidity. Phosphate was obtained from chemically pure $Ca(H_2PO_4)_2.H_2O$, thereby eliminating the calcium sulphate in superphosphate. In 1940 the potash was obtained from chemically pure KCl, while chemically pure KNO_3 was used in 1941. In the 1940 series lime, in the form of 3,850 pounds of chemically pure $CaCO_3$ per acre, was added to designated pots thereby raising their pH from 5.1–5.3 to 5.9–6.0. In the

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[1] Contribution No. 616 of the Rhode Island Agricultural Experiment Station.

1941 series 1,000 pounds of chemically pure $CaCO_3$ raised the pH to 5.3–5.6 in one group of pots, and 4,000 pounds of chemically pure $CaCO_3$ and 100 pounds of MgO raised the pH to 6.0–6.4 in the second group of pots. In 1940 certain pots provided with the equivalent of 36 pounds of magnesium (Mg) per acre from chemically pure $MgSO_4.7H_2O$ gave significant increase in yield; therefore in 1941 all pots received the equivalent of 60 pounds of Mg from technical grade MgO having a neutralizing power equal to 232 pounds $CaCO_3$. In 1940 boron equivalent to 15 pounds borax per acre was added to two pots with favorable response, so in 1941 the equivalent of 10 pounds of borax was added to all pots. Manganese at the rate of 30 pounds per acre of chemically pure $MnSO_4.4H_2O$ was added to all pots in 1941. The organic matter content of the soil varied from 3.46 per cent to 3.95 per cent.

Chloropicrin was applied to designated pots in 1 cubic centimeter doses (5 cubic centimeters per cubic foot) after all fertilizers had been added. A central hole three-fourths the depth of the pot was made, the chloropicrin injected, the hole refilled and the soil surface moistened with water to a depth of 1 inch. After 7 or 10 days, these pots were individually emptied on clean oilcloth, mixed to remove any residual chloropicrin and the soil replaced in the pots.

Cos or Romaine lettuce was used because of its adaptability to the

TABLE I—AVERAGE GREEN WEIGHT YIELDS, SOIL ACIDITY, AND SOIL NITRATE-NITROGEN AT HARVEST OF COS LETTUCE IN 1940 AND 1941

Treatment	Green Weight 10 Plants (Grams)	Acidity pH	NO_3/N (Ppm)
1940			
N, P, K	1.7	5.05	66
N, P, K; Chloropicrin	5.5	5.28	43
N, 3P, K	2.0	5.06	65
N, 6P, K	6.7	5.05	75
N, 6P, K; Chloropicrin	42.8	5.28	34
N, P, K	4.7	5.90	74
N, P, K; Chloropicrin	41.6	6.04	46
N, 3P, K	17.5	5.92	66
N, 6P, K	44.4	5.88	77
N, 6P, K; Chloropicrin	156.0	5.97	51
N, 6P, K; Chloropicrin, Boron	169.0	6.05	55
N, 6P, K; Chloropicrin, Mg	181.0	5.94	56
1941			
N, 6P, K	69.6	5.35	63
N, 6P, K; Chloropicrin	293.0	5.50	19
N, 6P, K; Manure	158.3	5.47	48
N, 6P, K; Manure, Chloropicrin	323.0	5.54	4
N, 12P, K	188.7	5.35	41
N, 12P, K; Chloropicrin	436.2	5.50	11
N, 24P, K	365.5	5.43	33
N, 24P, K; Chloropicrin	575.5	5.45	Trace*
N, 6P, K	157.0	6.10	45
N, 6P, K; Chloropicrin	417.5	6.17	14
N, 6P, K; Manure	266.3	6.25	22
N, 6P, K; Manure, Chloropicrin	478.0	6.25	Trace*
N, 12P, K	245.2	6.15	40
N, 12P, K; Chloropicrin	522.1	6.22	5
N, 24P, K	375.8	6.17	16
N, 24P, K; Chloropicrin	612.9	6.18	Trace*

*Trace—less than 2 parts per million.

conditions of the experiment and also because it is being grown in many glasshouses as a catch crop. In 1939 so much difficulty was encountered in getting a uniform stand because of the failure of the seed to germinate that the results were merely considered indicative and are not given in detail in this paper. In 1940 the Cos lettuce germinated none to well but the response to the various treatments was so striking that the results are presented in Table I. In the 1941 trial the seed germinated quickly after planting on September 9 and the plants grew vigorously until harvest on November 7.

1940 TRIALS

The 1940 series corroborated the 1939 results showing that in field soil cropped for over 40 years at the Experiment Station Farm a good crop of Cos lettuce could not be grown unless treated in some way. Liming to decrease acidity (Fig. 1) brought about a marked response. At both the high and moderate soil acidity and the low and intermediate phosphate level, chloropicrin soil treatment gave remarkable growth response, four to seven times. The addition of boron and especially magnesium further increased the growth (Fig. 1).

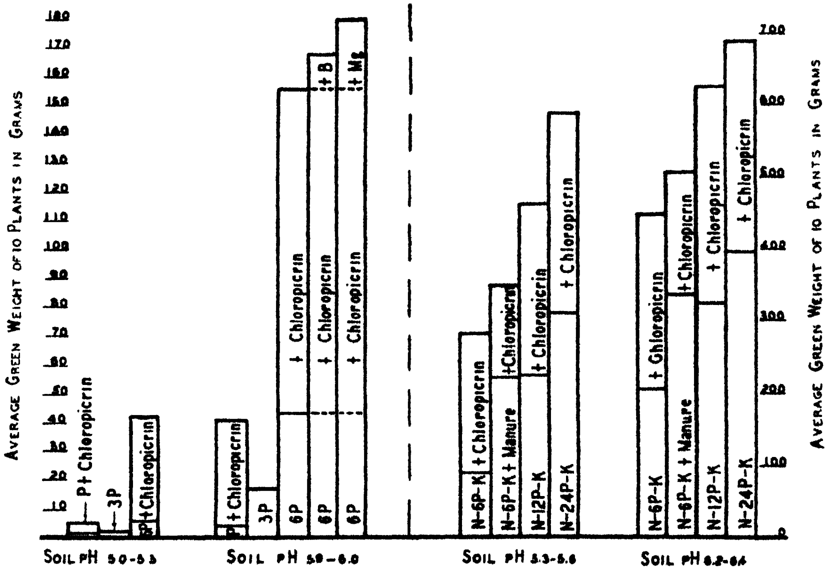

FIG. 1. Effect of phosphate applications and chloropicrin soil treatment on Cos lettuce grown at different pH levels. Left, 1940 data; right, 1941 data.

The effects on green weight, of increasing phosphate applications from 100 pounds to 600 pounds of P_2O_5 per acre, are shown in Fig. 1. Even at the degree of soil acidity (pH 5.0) where Cos lettuce was barely able to grow, the chloropicrin treatment increased growth by several fold. At these low phosphate levels and at a given pH, the chloropicrin treatment was equal to the P_2O_5 in 2,500 pounds of superphosphate per acre. At harvest, nitrates were lower in all chloropicrin-treated soils (Table I), which is ascribed to greater removal by the increased plant growth rather than to lack of ammonifying and nitrifying organisms.

1941 TRIALS

The 1941 data shown in Fig. 1 indicate that the grower of Cos (Romaine) lettuce in the type of soil used here should neutralize the acidity to a point above pH 6.0 for good results. While yields are increased materially by 2,400 pounds of P_2O_5, equivalent to 6 tons of 20 per cent superphosphate per acre, the increase is not arithmetically proportional to the increment added and lesser quantities are more economical. It will be noticed that 16½ tons of manure to the acre may be expected to produce a vegetative growth increase equivalent to the P_2O_5 in 1½ tons of 20 per cent superphosphate.

Chloropicrin soil treatment prior to planting greatly increased the green weight of Cos lettuce in soil which would be considered as harboring no microorganisms especially injurious to plant growth. Yet, Fig. 1 may be interpreted as showing that upsetting the biological balance in such a soil does promote better growth. It must be kept in mind that what was considered sufficient nitrogen and potash were added and that all other factors were uniform in the chloropicrin-treated and untreated soils.

The effect of chloropicrin soil treatment, soil acidity, and phosphate application on the green weight of Cos lettuce grown in 1941 is shown in Fig. 1. The effect of difference in acidity (pH 5.3 to 5.5 compared with pH 6.1 to 6.3) on vegetative growth is decreased as greater amounts of phosphate are added, or the greater the phosphate level in the soil the less acidity acts as a limiting factor of growth. Chloropicrin soil treatment gave at least a doubling of the yield and brought a proportionally greater growth response at the lower phosphate levels than at the higher.

From the grower's standpoint the results (Fig. 1) suggest that in soil with an acidity of pH 5.3 to 5.5 as is common in the northeastern states, equivalent yields might be obtained by treating the soil with 800 pounds of chloropicrin instead of the phosphate equivalent of 6,500 pounds of 20 per cent superphosphate per acre. If the grower uses lime sufficient to raise the soil pH to 6.1 then an application of 800 pounds of chloropicrin per acre may be expected to promote more growth than 4½ tons of 20 per cent superphosphate. While an application of 800 pounds of chloropicrin generally would not be profitable at present prices, other experiments indicate that applications of 320 pounds or even less give approximately similar results under favorable conditions.

CONCLUSIONS

It appears that cropped land may be producing much less than its capacity in some instances because the injurious and competitive microorganisms in the soil are not given due consideration. Chloropicrin soil treatments at the rate of 5 cubic centimeters per cubic foot prior to the cropping of the soil studied in this investigation removed the major factor inhibiting vegetative growth. Progressive increases in yields occurred with additions of monocalcium phosphate up to the equivalent of 12,000 pounds of 20 per cent superphosphate per acre and chloropicrin treatment concurrently about doubled these yields. It is clearly indicated that under the conditions of the investigation large applications of phosphate accompanying chloropicrin soil treatment gave best results and the same type of response may be expected in commercial use. The response to chloropicrin at a soil pH of 5.5 or lower is particularly interesting, because the toxic or inhibitory effect is usually ascribed to inorganic ions made soluble at that degree of acidity. This data suggests that the soil fungi and bacteria destroyed by the chloropicrin add significantly to the inhibitory effect.

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The Potency of Digitalis Purpurea Cultivated in New Hampshire[1]

By J. R. HEPLER, W. T. ACKERMAN, and BENJAMIN FRENCH,
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THE dried leaves of *Digitalis purpurea* are used in the preparation of a heart stimulant. Before 1938 most of the dried Digitalis was imported from Europe. Digitalis, however, has been grown in the United States as a flowering plant and has escaped from cultivation in New York and the Pacific Northwest (1). While the wild supply would be sufficient for our drug needs, its quality is so variable and often so low in the active glucosides of Digitalis that the less variable cultivated product is preferred for medicinal purposes (7).

The method of handling the crop is quite similar to that of early cauliflower. The seed is started in early March, pricked out into flats and transplanted to the field in late May or early June. Apparently, Digitalis likes wild conditions, since it grows very well in soil that has not been cultivated for a number of years. It also grows well in a sandy or gravelly soil. It will grow rapidly with apparently little fertilization provided it has enough water. It is necessary to cover overwintering plants to prevent heaving. The plant has a shallow root system, and will heave very readily unless protected.

Various fertilizers were used in 1940 on new land with comparatively unimportant results. Digitalis did not respond to the use of manure, or commercial fertilizer, or a combination of the two as a vegetable crop like cabbage or corn would have responded. The crop grows very rapidly during the cool, short fall days.

The yield of cultivated Digitalis varies like any other crop. The 900 plants reported on in this experiment grew on approximately ⅛ acre with a total yield of 2108.7 pounds, or 16,870 pounds fresh weight per acre. Since Digitalis dries down to about 15 per cent of its green weight, the yield of 16,870 pounds would equal 1,530 pounds or approximately ¾ ton of dried Digitalis. If all of the cutting had been made in late October, the yield would have been considerably over a ton per acre.

EXPERIMENTAL METHODS

In order to determine whether it would pay to start the plants early, an experiment was laid out with five planting dates a week apart. The Digitalis was cut on four dates 2 weeks apart to determine the amount of growth in fall. The spring season in New Hampshire is late, and on this particular field the earliest planting that could easily be made was on May 24. In fall the first cutting was made on September 6, and the others at 2-week intervals. Each series was replicated five times. There were 36 plants set on each planting date per plot, or a total of 180 plants per treatment. In fall, nine plants of each planting date or 45 plants per replication were cut on each date. The results in pounds per randomized plot of nine plants are given in Table I.

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[1] Scientific Contribution No. 5, Biological Institute, University of New Hampshire.

In order to test the reliability of the data in Table I these figures were subjected to an analysis of variance (2). The P value at 1 per cent for the date of harvest is 90 for the total plot yield. Since the differences in yield exceed 90 in every case except the September 20 to October 4 period, where the difference is 88, the figures are highly significant. In other words, the table shows that Digitalis will grow rapidly in the cool fall weather until it is so cold that it freezes.

TABLE I—Yield of Digitalis in Pounds per Plot of Nine Plants

Date of Harvest	Replication No.	Date of Planting					Total Yield Per Cutting
		May 24	May 31	June 7	June 14	June 21	
Sep 6............	1	16.0	19.6	10.8	14.4	6.8	—
	2	16.5	14.0	13.5	12.3	6.0	—
	3	15.5	20.4	17.1	11.5	7.0	—
	4	17.4	22.1	14.4	8.7	10.2	—
	5	21.3	12.6	16.1	9.5	5.6	—
Total............	–	86.7	88.7	71.9	56.4	35.6	339.3
Sep 20............	1	15.2	23.7	14.9	13.8	10.8	—
	2	18.4	17.4	19.9	12.5	7.0	—
	3	23.1	31.2	27.6	15.3	10.8	—
	4	22.2	25.4	20.7	24.0	13.3	—
	5	19.4	24.3	21.6	18.5	6.7	—
Total............	–	98.3	122.0	104.7	84.1	48.6	457.7
Oct 4............	1	21.1	26.1	21.0	20.8	16.3	—
	2	20.9	23.5	20.7	18.5	8.4	—
	3	26.7	30.5	32.9	15.9	11.3	—
	4	22.0	25.5	24.7	27.3	25.3	—
	5	24.2	30.2	23.4	17.8	10.0	—
Total............	–	114.9	135.8	122.7	100.3	71.3	545.0
Oct 18............	1	21.4	33.7	31.6	31.9	27.0	—
	2	38.2	36.3	32.9	24.9	11.7	—
	3	40.7	47.5	40.5	28.8	14.5	—
	4	34.9	36.6	36.9	37.5	30.5	—
	5	33.3	32.4	32.5	19.4	11.1	—
Total............	–	168.5	186.5	174.4	142.5	94.8	766.7
Grand Total ...	–	468.4	533.0	473.7	383.3	250.3	2108.7

As far as the planting dates are concerned, the analyses of variance data show that the P value at 1 per cent is 80 pounds. The difference in yield between May 24 and May 31 is –64.6 pounds; between May 31 and June 7 is 59.3 pounds; between May 31 and June 14, 149.7 pounds; and between May 31 and June 21, 282.7 pounds. The latter two yields are highly significant. Apparently, the best time to transplant Digitalis to the field is about the same time tomatoes are transplanted in New Hampshire, that is, around June 1.

One of the biggest difficulties in commercial Digitalis culture for the small grower is the drying of the product. When the leaves are gathered from the wild plants, in June or early July of the second year of growth, they are stripped from the flowering stalk before the flowers open. At this time the drying may be done naturally and quickly in the shade. If, however, the crop is grown for fall cutting as is the case in New Hampshire, it is almost impossible to dry the leaves except by artificial means. The leaf is rather fleshy with a long and heavy petiole and midrib. This petiole and midrib resists drying to such an extent that a plant hung in an attic often takes from 4 to 6 weeks to dry down to a required moisture content of 8 per cent of the dried product. In fact, in moist weather the product often molds and becomes practically worthless. In any case, it is likely to turn dark, although this is not necessarily an indication of poor quality or that it is low in the active glucosides of Digitalis.

Since it has been shown that Digitalis does most of its growing during September and October, the crop should be cut late in the year and dried quickly by artificial means. This required the building of a drier in which the heat can be raised to a temperature of 150 to 160 degrees F and the air changed rapidly. The construction of such a unit is not very simple, because of the difficulty of changing the air and getting the same temperature in all parts of the drier.

The drying chamber that was constructed for these experiments had inside measurements of 8 feet high, 4 feet long, and 4 feet wide. It was built of insulating material nailed on both sides of 2 by 4 studs. It had a capacity of 22 trays; each tray holding from 10 to 12 pounds of fresh Digitalis leaves or a total load of around 200 pounds. A depth of more than two leaves per tray of fresh leaves lengthened the drying time so much that it was found impractical to use more than two layers.

Since considerable differences in temperature in the drier itself (25 to 30 degrees) were found even with a forced draft, it was found necessary to force heated air through the hollow walls into the drier through holes between each set of trays. A large fan was used to force the air into the drier and enough pressure was formed to force the air to approximately the middle of the trays. It was then drawn up through the trays themselves and out of the cabinet through a hole in the middle of the top with another fan. When this system of air flow was used, a drier full of leaves could be dried in 24 hours with an air temperature around 150 degrees F.

Another drying problem concerns the drying of the leaf stalks or petioles. In Table II on Digitalis assay, it may be noted that sample No. 30 consisted of leaf blades and sample No. 3 of petioles. The potency of the leaves themselves was 117 per cent of standard, and for the stems 87 per cent of standard. Before the leaves are dried, there are approximately equal quantities of stems or petioles and leaf blades. After drying, however, 60 per cent of the remaining weight is in the leaves, and 40 per cent in the dried petioles. With the very low glucoside content in the petioles, it would seem that it might be profitable to dry only the leaf blade, especially since the leaf blade will dry in approximately half the time it takes to dry the leaves with the petioles, and since the physiological activity of the leaves is approximately 50 per cent higher than that of the petioles.

A number of assays were made of New Hampshire Digitalis at the National Institute of Health of the United States Public Health Service under the direction of Dr. M. I. Smith. Table II gives analyses of these samples, all of which were grown and dried in Durham, New Hampshire, and Table III gives analyses of samples which were gathered in various sections of central and western New Hampshire and represent different cultures of Digitalis as grown in various parts of the state.

TABLE II—DIGITALIS ASSAY, MARCH 1941, U. S. P. XI METHOD*
(SAMPLES RECEIVED JANUARY 1, 1941)

No.	Date Harvested	Drying		Potency (Per Cent)	Notes on Leaves
		Hours	Degrees F		
1	Sep 9	50	140	117	———
8	Oct 28	32	150	140	———
4	Oct 1	30	150	140	Wilted 21 hours
5	Oct 3	60	125	140	Wilted 15 hours
13	———	6 weeks	Air dried	117	———
3	Sep 19	50	135	117	Tops
30	Sep 19	40	135	87	Stems
12	Dec 10	10	140	117	Frozen
11	Nov 25	2¼	200	87	Frozen
10	Nov 21	1⅔	225	58	Frozen
9	Nov 20	2	250	32	Frozen
100	Nov 21	1⅔	300	14	Frozen
Standard	———	———	———	100	———

*All assays given in this paper were made by the National Institute of Health of the United States Public Health Service under the direction of Dr. M. I. Smith.

In general these analyses show that Digitalis has a little higher potency in October and late September than in early September, and that drying temperatures up to 125 to 150 degrees F will not impair the physiological activities of the Digitalis. However, samples Nos. 11, 9, 10, and 100 plainly show that if dried at the higher temperatures of 200 degrees or above most of the active principles would be destroyed. In fact, these samples did not look like dried samples, but looked charred.

It was interesting to note that freezing apparently did not affect the potency of the Digitalis particularly. Sample No. 12 was gathered December 10, and was covered with snow, yet showed an activity

TABLE III—ASSAY OF *Digitalis Purpurea* (SAMPLES COLLECTED BY W.P.A. PROJECT IN NEW HAMPSHIRE, FALL OF 1940)*

	Soil	Harvested		Potency	Notes on Leaves
1	Ordinary garden Central New Hampshire	Sep 15	Air dried 7 days, 90 to 110 degrees F, 2 days	100	———
2	Ordinary garden Central New Hampshire	Oct 1	90 to 110 degrees F, 2 days	117	———
3	Ordinary garden Central New Hampshire	Oct 15 22 degrees F	90 to 110 degrees F, 3 days	117	———
4	Gravelly, Connecticut River Valley	———	110 to 119 degrees F, 3 days	175	Leaf blades only
1A	Same as 2 and 3	Dec 15; 8 inches snow, ground frozen 5 weeks	Same as 2 and 3	117	———
2A	Pooled samples "poor grade"	———	———	117	———
3A	Pooled samples "best grade"	———	———	117	———

*One hour frog method, U. S. P. XI, p. 397. Tincture from first year leaves powdered to pass 20 mesh sieve.

content of 117. The official temperature December 2, 1940 at Durham, New Hampshire, or 8 days before this sample was harvested was –18 degrees F (Table III).

Among the samples gathered over the various parts of the state, the one gathered in the Connecticut River Valley was grown on gravelly soil and only the leaves were dried. This sample showed a potency of 175. The sample gathered September 15 (1) showed a potency of 100, on October 1, (2) 117, and on October 15 (3) 117. This latter sample had been subjected to an outdoor temperature of 22 degrees F. The sample gathered December 15 (1a) was taken from a field with 8 inches of snow on it. Even though the ground had been frozen for about 5 weeks and had gone through a minimum temperature of around –20 degrees F early in December, it showed a high potency. It is interesting to note that samples which were called poor grade, brownish in color (2a) assayed as high as the best samples which were greenish in color (3a).

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The Effect of Pruning Established Rose Bushes on Bloom Production

By J. C. Ratsek, *Texas Agricultural Experiment Station No. 2, Tyler, Tex.*

MOST of the popular literature on pruning of garden Hybrid Tea roses recommends severe spring pruning of established bushes. A test was started in 1939 to determine the best pruning practice for southern gardeners.

METHOD

Two-year plants of Talisman budded on Multiflora-Welch strain, were planted 24 inches apart in 6-foot rows on March 4, 1939. Differential pruning was given in March 1940 and 1941 as shown in Table I. Plants were thinned to two to five canes of the previous season's growth and topped to 4, 12, and 20 inches, and no topping. A fifth group of plants received neither topping nor thinning the first year but differential pruning and thinning the second year as shown in Table II.

Plants were fertilized May 8 and August 17, 1940 and May 15 and August 1, 1941 with a 6–9–3 fertilizer at the rate of 200 pounds per acre. Plants were dusted regularly with 325 mesh sulphur in 1940 and a 90–10 sulphur "Tennessee Copper 34" mixture in 1941 to control blackspot. Bloom counts were taken at 2- to 5-week intervals depending upon growth of plants. All blooms counted were cut off at the peduncle.

Two-year bushes of Red Radiance and of Talisman were planted in January 1940. Red Radiance a relatively strong grower was selected to determine whether pruning would effect this variety in the same manner as for the weaker growing Talisman. The Talisman plants were given differential pruning in spring of 1941. The stem length as well as the number of blooms produced was recorded. Blooms were cut just above the second five-leaflet leaf at the base of the stem. On short stems where no five-leaflet leaves were present the bloom was cut just above the top leaf at the base of the peduncle. Five plants were used in each plat.

RESULTS

Table I indicates the results obtained following spring pruning of

TABLE I—EFFECT OF HEIGHT OF PRUNING ON BLOOM PRODUCTION

Treatment	Talisman				Red Radiance	
	1940		1941		1941	
	No. Plants	Average No. Blooms Per Plant	No. Plants	Average No. Blooms Per Plant	No. Plants	Average No. Blooms Per Plant
Pruned 4 inches, thinned...	39	122.0	34	103.4	39	72.4
Pruned 12 inches, thinned...	39	183.2	36	136.1	—	——
Pruned 20 inches, thinned..	39	196.3	34	154.4	—	——
Thinned only............	37	219.2	32	161.2	37	104.2
Check, no treatment.......	158	303.0	16	180.0	—	——

rose bushes to different heights. The more severe the pruning the less the number of blooms produced. In 1940 plants receiving no pruning were 6 feet high and produced some 300 blooms for the season as compared to 3-foot plants producing 122 blooms for those pruned to 4 inches.

In 1941 the bloom production of the less severely pruned plants was lower than in 1940 due to considerable blackspot as a result of a wet growing season and to crowding. The unpruned, unthinned plants reached a height of 7 to 8 feet. Results of differential pruning of Red Radiance indicate that severe pruning reduces the number of blooms in the same manner as it does for the Talisman.

Table II shows the results obtained from differential pruning and pruning and thinning. In general, little difference in the number of blooms produced resulted from thinning of plants with the possible exception of the unpruned plants. Here results are the reverse obtained in the previous experiment, in that no pruning or thinning resulted in more blooms than the no pruning alone. The difference was probably due to the crowding of the plants used in the second test. These plants received no differential pruning in 1940 and consequently were larger plants than the unpruned-thinned plants in first experiment which did receive the differential pruning. Being larger, competition was keener and bloom production less.

TABLE II—EFFECT OF PRUNING AND THINNING ON BLOOM PRODUCTION (TALISMAN)

Treatment	No. Plants	Average No. Blooms Per Plant
Pruned 8 inches	17	171.4
Pruned 8 inches and thinned	19	160.0
Pruned 20 inches	18	165.3
Pruned 20 inches and thinned	19	161.7
Pruned 32 inches	18	192.8
Pruned 32 inches and thinned	19	203.8
Check, no treatment	16	180.0
Thinned only	17	205.7

Table III presents the results of different heights of pruning on

TABLE III—EFFECT OF PRUNING ON NUMBER AND STEM LENGTH OF BLOOMS (TALISMAN)

Height of Pruning (Inches)	Plat*	Number of Blooms with Stem Length (Inches)				Average Total Number Blooms Per Plant
		1 to 6	7 to 12	13 to 18	19 to 24	
4	A	149	95	4	0	—
	B	128	69	4	0	—
Average number per plant		27.7	16.4	0.8	0	44.9
12	A	186	51	3	1	—
	B	230	42	1	1	—
Average number per plant		41.6	9.3	0.4	0.2	51.5
20	A	203	40	5	1	—
	B	203	50	6	1	—
Average number per plant		40.6	9.0	1.1	0.2	50.9
None	A	233	73	13	5	—
	B	229	64	15	1	—
Average number per plant		46.2	13.7	2.8	0.6	63.3

*Five plants per plat.

stem length. Four-inch pruned plants produced proportionately more 7- to 12-inch blooms and proportionately less 19- to 24-inch blooms than did the other treatments. The no-pruned plants produced a relatively high proportion of 1- to 6-inch stemmed plants. In addition, however, they did produce more blooms with 13- to 18-inch and 19- to 24-inch stems than any of the pruned plants. It is evident, therefore, that the benefit most often suggested in favor of severe pruning, namely that more large stemmed blooms are produced, is not necessarily true under all conditions. The differences in total number of blooms produced between the various treatments are not as great as they were in the tests alone. This was probably due to the method of taking the bloom counts. In this study, blooms were cut with long stems and leaves. In the other tests, blooms were removed at the peduncle, all leaves remaining on the bush. Removing stems with leaves is a pruning process. As such it would tend to narrow the margin of difference between the various preliminary pruning treatments.

Of particular interest was the difference in color of the first crop of blooms on the plants given different pruning treatments. The more severe the pruning the paler the color. As pointed out in a previous paper (1) this would indicate that severe pruning results in a reduction of carbohydrates necessary for normal plant growth by removal of wood which contains the stored plant food.

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The Effect of Sulphur on Growth of Roses in an Alkaline Soil II. Results for 1940 and 1941

By J. C. RATSEK, *Texas Agricultural Experiment Station No. 2, Tyler, Tex.*

WORK was initiated in 1937 at the Denton Experiment Station to determine the feasibility of soil acidification with sulphur and its effect on growth of Hybrid Tea roses. The soil on the acre plot selected was a black "waxy" calcareous prairie soil of the San Saba series. The initial pH range varied from 7.2 to 7.9.

Samples of soil taken at regular intervals were titrated for buffer capacity to sulphuric acid. Based on the resulting buffer curves the amount of sulphur required to drop the pH to various levels was calculated and applied to the soil. Bloom counts were taken as a measure of the plant growth. Results of the first two years were reported in a previous paper (3). Results of 1940 and 1941 are reported in this paper.

RESULTS

Table I indicates the additional sulphur applied during 1940–41 and the pH of the soils of the various plats under test. In general the pH

TABLE I—EFFECT OF SULPHUR ON SAN SABA SOIL

Plat No.	pH Wanted Jun 14, 1940	Pounds Sulphur Added (Check)	Average pH of Soil						Chlorosis*			
			1940			1941			Talisman		Radiance	
			Apr 27	Jun 19	Sep 12	Mar 6	Jul 30	Sep 22	Jul 30, 1940	Jul 30, 1941	Jul 30, 1940	Jul 30, 1941
1A			7.6	7.8	7.5	7.4	7.7	7.4	5.2	5.6	1.4	2.6
2C			7.8	7.5	7.5	7.2	8.1	7.6	6.8	7.2	1.4	5.1
4A			8.0	8.2	7.8	7.7	8.1	7.9	6.9	8.0	1.4	5.7
6E			7.9	8.0	8.0	7.7	7.7	8.1	6.2	7.6	1.6	5.3
1B	7.5		7.5	7.5	7.6	7.1	7.8	7.6	3.6	5.9	1.4	2.4
2D			7.4	7.7	7.6	7.3	8.0	7.4	6.6	5.7	1.3	4.7
4B		4	7.8	8.1	7.7	7.6	8.2	7.8	7.1	7.7	1.4	4.3
5D		4	7.8	8.1	7.8	7.5	7.5	7.9	6.2	6.8	1.5	5.1
1C	7.0	10	7.2	6.1	5.8	6.2	6.3	6.3	2.7	5.6	1 3	2.9
2E		5	7.1	7.2	7.4	6.9	6.8	7.2	3.9	5.8	1.3	5.0
4C		10	7.3	7.4	6.9	6.2	7.6	7.6	5.3	5.7	1.3	3.7
5E		10	7.6	7.4	7.8	7.0	7.9	7.7	5.6	7.3	1.4	4.4
1D	6.5	20	7.0	6.4	5.1	5.5	6.2	6.4	3.5	3.2	1.4	2.3
3A		20	7.3	8.0	7.3	6.9	7.4	7.5	4.3	4.8	1.2	3.7
4D		30	7.3	7.8	7.2	6.2	6.9	7.1	3.8	5.1	1.4	2.1
6A		30	6.8	7.5	7.3	7.1	7.6	7.6	5.4	7.0	1.2	3.5
1E	6.0		7.2	6.1	6.8	6.1	6.5	7.1	3.5	3.2	1.3	2.4
3B			5.9	7.4	6.3	7.1	7.2	7.3	3.6	3.6	1.3	2.5
4E		40	7.2	6.7	6.7	4.6	5.5	5.9	3.2	3.5	1.2	1.2
6B			5.8	7.4	7.0	7.1	7.5	7.4	3.7	5.2	1.2	3.9
2A	5.5	40	6.6	7.2	6.8	5.5	6.3	6.5	4.0	2.2	1.2	1.2
3C			4.4	6.5	6.8	6.9	7.1	6.2	3 1	3.1	1.3	1.6
5A		40	6.9	7.2	6.0	5.3	6.7	6.9	2.5	2.5	1.2	1.1
6C			7.0	7.4	7.2	7.0	7.5	7.4	3.3	4.8	1.3	2.3
2B	5.0	40	6.5	6.0	6.5	4.7	6.0	5.5	2.3	1.2	1.2	1.1
3D		20	5.1	5.6	6.4	5.6	5.9	6.1	2.5	2.1	1.2	1.0
5B		40	6.2	5.6	5.6	4.5	5.7	5.3	2.9	1.3	1.1	1.0
6D		40	5.8	6.6	5.7	6.2	5.4	6.4	3.5	3.1	1.2	1.2

*One green leaf to eight white leaves.

values were somewhat higher than the preceding two years (3). Chlorosis which was not apparent to any degree in 1938 and 1939 was severe in 1940 and more so in 1941. Even Radiance which is able to withstand considerable lime in the soil without showing chlorosis exhibited chlorosis in the alkaline plats. It was suggested in a previous report (3) that the lack of chlorosis was probably due to the high tonnage of organic matter turned into the soil the spring of 1937. With the breakdown of the organic matter and subsequent reduction in CO_2 and possibly organic acids the iron in the soil became unavailable to the plant and chlorosis resulted.

Table II indicates the results of varying soil reactions on the production of blooms. In general there is an increase of blooms with an increase in soil acidity. One variation from this generality is to be found in both Talisman and Radiance. Instead of a gradual increase in the number of blooms with increments of acidity, there is a low point at pH 7.5 for Talisman and 6.5 for Radiance. This depression in production becomes more apparent when the average bloom production for 4 years is considered (Table II).

TABLE II—SUMMARY, EFFECT OF pH ON BLOOM PRODUCTION OF ROSES

pH Wanted (Check)	Average No. Blooms Per Plant				Average No. Blooms Per Plant 1939–42	
	Talisman		Red Radiance			
	1940	1941	1940	1941	Talisman	Red Radiance
	289.4	90.4	292.2	227.6	127.1	163.5
7.5	226.2	91.8	283.6	229.2	106.7	159.4
7.0........	239.5	112.6	299.2	188.0	119.0	156.7
6.5..	280.0	147.3	240.7	151.6	141.4	129.0
6.0	293.4	120.8	291.9	195.4	142.3	160.0
5.5.......	300.7	170.2	284.2	249.5	159.4	170.6
5.0..... .	320.0	159.4	313.0	280.0	164.8	185.6

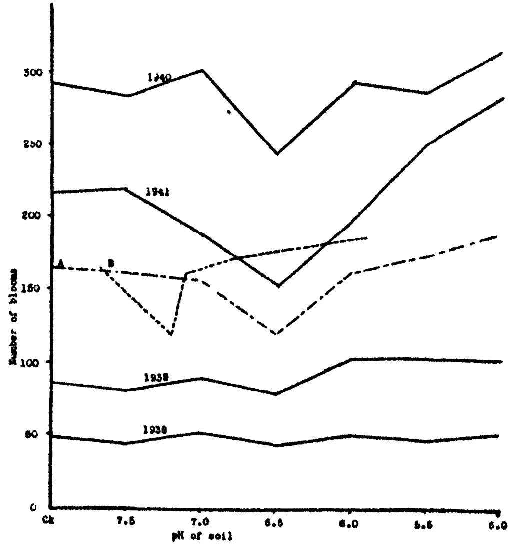

FIG. 1. Effect of pH of soil on bloom production of Radiance. A, 4-year average; B, 4-year average plotted on basis of true average pH.

Figs. 1 and 2 show graphically the depression in bloom production of the two rose varieties at the two pH levels. This phenomenon is not due to soil variation since the depression is in general present in most of the replicates. Furthermore, if it were due to soil variation it should effect Talisman and Radiance alike since both varieties were present in each plat. The depression seems to be in the 7.5 plats for Talisman and the 6.5 plats for Radiance.

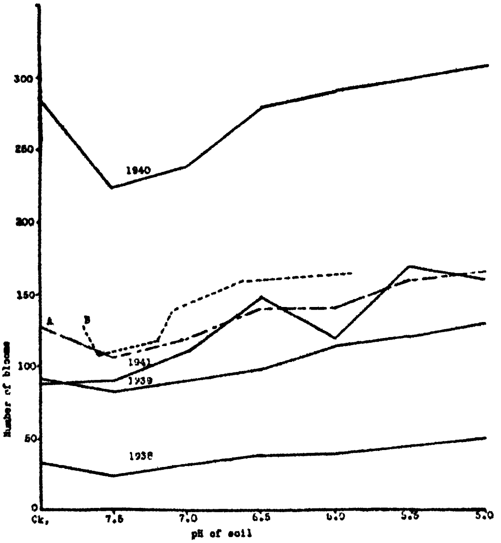

FIG. 2. Effect of pH of soil on bloom production of Talisman. A, 4-year average; B, 4-year average plotted on basis of true average pH.

The pH's given are not the true ones but the desired ones. In Figs. 1 and 2 line A represent the average bloom production for the 4 years 1938–41 at the "desired pH's" whereas line B represents the production at the true average pH for the 4-year period. The term true is used advisedly, for while these averages are based on pH determinations, the variation from year to year and from replicate to replicate make them only approximate. The new values for the depression point based on the average of pH determinations were 7.6 for Talisman and 7.2 for Radiance. It is probable the true point if such there is, lies close to 7.5 for Talisman and somewhat between 6.5 and 7.2 for Radiance.

Much work has been done by investigators on the relationship between pH of the medium and plant growth in water and soil cultures. Salter and McIlvane (4), Hixon (2), Arrhenius (1) and others working with corn, wheat, oats, alfalfa and other plants found that in water and soil cultures these plants have a minimum growing pH with two maxima at H ion concentrations just above and below the point of minimum growth. The general explanation for the depression of growth is made on the basis of an isoelectric point for water absorption by plant tissues. At the isoelectric point water absorption is slow and plant growth is depressed.

It would seem reasonable that this same explanation would apply to the rose bushes in this particular experiment. The depression was more evident in succeeding years as plants increased in size and produced more blooms. The depression in Talisman was less evident than for Radiance probably because chlorosis at the higher pH levels reduced growth sufficiently to mask the effects of high pH on the production of a maximum on the alkaline side.

There seems to be no correlation between growth depression point and chlorosis. Increased chlorosis was correlated with increased pH. It is evident, therefore, that we may have another factor to consider besides the effect of pH and calcium on salt (particularly iron) intake by the plant. In the past there has been much evidence that rose bushes will grow on alkaline soils. It is more than likely that the soil pH was such that plant growth was in the region of a high alkaline maximum. In the presence of organic matter, or of soluble iron in the form of sulphate and so on, or if alkalinity was due to sodium rather than to calcium, it is likely that chlorosis would be low and plants would grow well. They would grow better under this more alkaline condition than at a lower pH if the latter was in the region of minimum growth. If the pH was lowered still more it is probable that growth would have exceeded that at the alkaline maximum. At least this was the case with the rose bushes under the conditions of this experiment.

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The Effect of Light Intensity on the Photosynthetic Efficiency of Carnation Varieties[1]

By W. D. Holley, *New Hampshire Agricultural Experiment Station, Durham, N. H.*

A WIDE difference in the winter production of carnation varieties, especially in the region around the Great Lakes is well known to florists. Are the more prolific varieties capable of utilizing lower light intensities more efficiently? Experiments were designed to give an answer to this question.

Materials and Methods

The three varieties of carnations used were: Morning Glow, a good producer from the standpoint of the number of blooms; Maine Sunshine, an average producer; and Pelargonium, a poor producer under Central Michigan conditions.

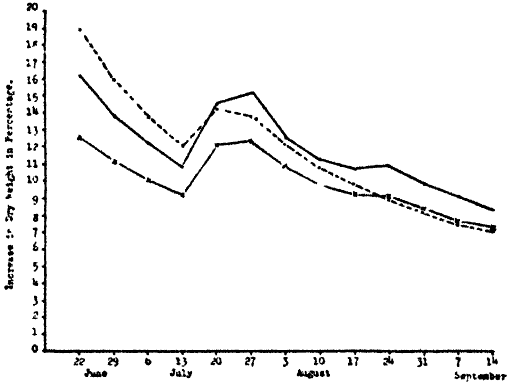

Fig. 1. Rate of growth of three varieties of carnations during the summer months, 1939.

Pelargonium ----; Morning Glow ———; Maine Sunshine x—x—x—

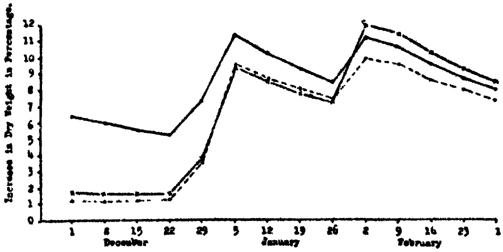

Fig. 2. Rate of growth of three varieties of carnations during the winter months, 1939–40.

The relative summer and winter growth rates of these varieties under natural daylight conditions were determined by dry weight accumulation over 3-month periods. Thirty-five whole plants of each variety, selected at random, were washed and dried to constant weight at approximate monthly intervals.

Since the dry weights were not taken at regular intervals, they were calculated to a weekly basis, in order properly to derive and compare the relative growth rates of the three varieties. For this procedure use was made of the equation: $R/100 = \log W_2 - \log W_1$, in which $R/100$ is the increase in dry weight in percentage, W_2 is the weight at the end and W_1 the weight at the beginning of a period. For convenience of calculation, this equation was given the form: $R/100 = 2.302585 \log W_2/W_1$. The summer and winter growth rates are shown in Figs. 1 and 2.

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[1] This material is a part of the author's thesis for Master of Science Degree at Michigan State College, East Lansing, Michigan.

The second part of this experiment was designed to determine the comparative leaf efficiency of the three varieties by using the "twin- or opposite-leaf" method of sampling described by Denny (1). Carnations were found to have identical opposite leaves by the author.

In August, the three varieties were planted in alternating rows in a 21 foot bench on the east side of a carnation house. They were planted in the same soil mixture used for commercial production.

In adapting the "twin-leaf" method of sampling to carnations, it was first necessary to find some method of measuring the leaf area. This was done by blueprinting 160 leaves of each variety and measuring them with a planimeter. The area (y) of each of these leaves was then plotted against the length (x) and the curve of best fit derived by the method of the least squares. The resultant relationship was parabolic in type. The derived equations for the three varieties were as follows:

Morning Glow $y = -4.8888 + 6.476x - 0.6882x^2$
Maine Sunshine $y = 0.0169 + 0.327x + 0.0161x^2$
Pelargonium $y = -0.0081 + 0.388x + 0.0056x^2$

This made it possible to determine areas accurately on the simple basis of measurements of leaf lengths.

Since the "twin-leaf" method of sampling on carnations involves pulling the leaves from the stems with a downward motion, it was necessary to calculate the approximate error in sampling. Duplicate samples of 50 opposite leaves were dried to constant weight and their weights compared. Five replications were made for each variety. The maximum error involved in sampling was ± 0.44 per cent for Maine Sunshine; ± 0.77 per cent for Morning Glow; and ± 1.67 per cent for the variety Pelargonium.

Samples were taken under different intensities of light, which were obtained by using natural daylight, 500 watt, and 1000 watt Mazda bulbs during cloudy weather. The lowest light intensities were obtained by shading with black cloth. Light intensity readings were taken every hour by means of a General Electric photoelectric galvanometer and an average of these readings used as the light intensity for the daily period. Temperature readings were also taken and averaged in the same manner.

In sampling, one of a pair of opposite leaves was taken at 8 a.m. and the other taken at 5 p.m. Approximately 50 leaves were taken in each sample. After lengths of leaves were measured for each variety, the samples were dried to constant weight in an oven at 70 degrees C. The increase in dry weight over the 9-hour period was used as a basis for comparison of leaf efficiency. Samples were taken under various light intensities throughout January, February, and March.

RESULTS

Fig. 1 shows little difference in the relative growth rates for the three varieties, except for a slightly lower mean rate for the variety

Maine Sunshine. However, Fig. 2, covering the period during winter months when light conditions were much less favorable, shows the variety Morning Glow to have a considerably higher growth rate than either of the other two varieties. Percentages[2] of possible sunshine which occurred during this period were as follows: December, 1939, 23 per cent; January, 1940, 14 per cent; and February, 1940, 31 per cent. Not only was there an increase in number of hours of sunshine in February over the two previous months, but also an increase in light intensity during the cloudy days. Mid-day light intensity in the greenhouse frequently dropped to 100 to 200 foot-candles during December and January. The lowest corresponding intensity for February was 315 foot-candles.

The amount of photosynthate in grams per squar meter of leaf area, over 9-hour periods, is presented in Table I. It is at once apparent that temperature plays an important role in photosynthate accumulation. Since it was not possible to keep the temperature constant, samples were taken under different temperatures as well as different intensities of light.

TABLE I—PHOTOSYNTHATE PRODUCED UNDER DIFFERENT CONDITIONS OF LIGHT AND TEMPERATURE

Variety	Light 35 Temp.* 56.6	46 57.1	59 64.2	64 69.0	98 72.5	Total
Low Light Intensities (In Foot-Candles)						
Morning Glow..	-0.655	1.454	0.988	0.898	-0.864	1.821
Maine Sunshine..	-0.382	0.483	1.452	-0.136	-1.607	0.190
Pelargonium.....	0.180	-0.624	-0.883	0.876	-4.143	-4.594
Medium Light Intensities (In Foot-Candles)						
	Light 546 Temp.* 55.0	640 58.0	765 58.0	850 62.0	970 66.3	Total
Morning Glow. ..	1.557	1.545	2.775	1.046	3.109	10.030
Main Sunshine ..	0.878	0.980	2.185	2.656	1.555	8.254
Pelargonium ..	0.918	3.065	2.813	1.676	4.313	12.785
Higher Light Intensities (In Foot-Candles)						
		Light 1502 Temp.* 62.2	1615 59.0	2043 67.0	2043 67.0	Total
Morning Glow....		3.982	6.082	6.256	7.423	23.723
Maine Sunshine		7.260	3.695	12.991	10.487	34.433
Pelargonium.......		7.576	6.395	10.132	9.365	33.468

*Temperature in degrees F.

The total amount of photosynthate produced by a variety under a series of light intensities, as presented in Table I, is of little significance, since each set of conditions within the series is different. However, the efficiency of a variety under a given set of conditions is exemplified somewhat in the totals.

Under low light intensities, Morning Glow was the most efficient under a majority of the light intensities and temperatures tried. Both Maine Sunshine and Pelargonium accumulated significantly more photosynthate at higher intensities than did Morning Glow.

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[2] Obtained from the United States Weather Bureau Station at East Lansing, Michigan.

Discussion and Conclusions

The growth curves for the three varieties of carnations used in this experiment correspond favorably to their production records. During the summer months, when light is not a limiting factor, relative growth rates were similar.

The relative growth rates for the three varieties during the dark months were in the order of their productive ability. Morning Glow showed a much higher growth rate than the other two varieties and had a tendency to produce more new shoots in both summer and winter. This higher growth rate for Morning Glow may indicate only that the conditions of this experiment were more suitable to the variety. It does not necessarily mean that limited light was the sole cause of the slower growth rates in the other two varieties. However, since growing conditions of the experiment were those ordinarily given in commercial production, it is possible to say that Morning Glow exhibited the highest photosynthetic efficiency under these conditions.

Evidence obtained from this experiment indicates that in production of carnations, temperature becomes increasingly important when light intensity decreases. Under low light intensities of 100 to 200 foot-candles, photosynthate production may be so low that the amount of material respired easily exceeds that manufactured. This, in itself, may account for the poor production and quality of flowers obtained by careless growers.

Porter (2) found that some tomato plants accumulated more food than others under low light intensities. This is also true of carnation varieties. The varietal differences in amount of accumulated dry materials are probably due to differences both in the rate of respiration and in rate of photosynthesis.

The response of the Pelargonium variety to temperature under low light intensities indicates that it may be possible to increase the quantity and quality of flowers on many low producing varieties by growing them at still cooler temperatures. Perhaps Pelargonium, and many other similar varieties, should be grown at 45 degrees F during the cloudy months while Morning Glow, and similar varieties, may grow more favorably at 50 to 55 degrees F.

The data show that varietal differences in dry weight accumulation under low light intensities are not as pronounced at higher intensities. Varieties showing a relatively high leaf efficiency under low light intensities may be relatively less efficient under high intensities.

Carnations respond most favorably to light intensities of 1500 foot-candles or more.

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Carnations in Various Nutrient Solutions and Substrates[1]

By GEORGE BEACH, *Colorado State College, Ft. Collins, Colo.*

COLORADO carnation growers are showing an increasing interest in nutrient solutions for the commercial production of the crop. This paper reports a single year's results in the comparison of 10 different substrates and 10 different solutions used with carnation variety Patrician in the Horticultural Department greenhouse of Colorado State College.

The formula for a solution which might be called "Colorado Carnation Solution" is developing as a result of the study thus far. Of the substrates used, gravel and vermiculite appear to be the best. The purpose of this work is to find what alteration, if any, in solutions and substrates successful elsewhere is necessary for Colorado conditions.

Two hundred forty plants, all of the same variety, were grown on thirty separately waterproofed, subirrigated plots on a greenhouse bench. There were three replications each of seven different treatments and nine single, unreplicated plots.

The salts used were: KNO_3; $(NH_4)_2SO_4$; $Ca(H_2PO_4)_2$; $MgSO_4$; and $CaSO_4$.

In the "low NO_3" solution the K level was maintained with KCl. In the "low K" solution the NO_3 level was maintained with NH_4NO_3.

The check solution used here was Ohio WP, and compared to it were solutions in which the proportions of nitrogen, phosphorus, and potash were altered as follows:

High nitrate and potash: Double the amount of nitrate and potash and one-half the amount of phosphate.

Low nitrate and potash: One-half the amount of nitrate and potash and double the amount of phosphate.

Low nitrate: One-fourth the amount of nitrate.

Low phosphate: One-fourth the amount of phosphate.

Low potash: One-fourth the amount of potash.

The seventh replicated treatment was soil. The nine single plots are described later.

An interesting (and often confusing) phase of the problem is that in changing the amount of one element in the nutrient solution, the relative proportions of others are also changed, thus: with KNO_3 in the original solution, to make the low NO_3 solution mentioned above, the K is also reduced, necessitating addition of KCl and thus introducing an additional ion not in the check solution.

Clapp and Folley (2) noted nitrate deficiency symptoms in carnation plants given an excess of potash. Monopotassium phosphate was the potash carrier, so that phosphate was also increased. Since both phosphate and potash had been increased, the nitrate was relatively lower than that of the check solution. Post (4) states that in

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[1] Completes the crop year reported in part by Beach (1).

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soil plots high nitrogen increased production, at the same time increasing splits. Pember and Adams (3) on the other hand report a decrease in the number of splits when nitrogen is added in large amounts.

Many examples could be cited in which seemingly contradictory results arise from apparently similar treatments; treatments similar, for example, in the amounts of an element used but dissimilar in the proportion of the element to others in the same solution.

The ability of many plants to satisfy their nutritional needs from solutions varying widely in composition and concentration has been demonstrated. Possibly there is an optimum composition and concentration for every age and environment of a given plant. However, it seems logical to suppose that certain proportions of the necessary elements would be better than other proportions as has been amply demonstrated with grain seedlings by Tottingham and others (5).

As previously reported (1) sand, fine gravel, and vermiculite at first gave best results of the 10 different substrates compared. During winter, however, sand appeared to be water-logged much of the time and roots were shallow. This narrowed the choice to fine gravel and vermiculite which, all things considered, seemed best of the original 10 substrates.

Table I shows the yields of cut flowers on the various substrates and nutrient solutions.

TABLE I—PRODUCTION OF CUT FLOWERS ON 240 PLANTS OF CARNATION VARIETY PATRICIAN (APRIL 4, 1940 TO MAY 10, 1941)

Rank	Ohio WP is the nutrient solution unless otherwise indicated	Average Flowers Per Plant	Total	Split	No.	Eight-Plant Series* 1	2	3
1	High NO_3 and K (sand)	13 1/2	108	29	79	29–79	—	—
2	WP and NH_4NO_3 (unleached sand)	13	104	18	86	18–86	—	—
3	Low NO_3 and K (sand)	12 3/8	99	17	82	17–82	—	—
	Quartz and bentonite	12 3/8	99	24	75	—	—	24–75
4	Vermiculite	11 1/3	272	43	229	21–75	14–84	8–70
	Fine gravel	11 1/3	272	24	248	7–94	11–89	6–65
5	Sand	10 1/6	244	39	205	11–75	20–60	8–70
6	Low PO_4 (sand)	10	80	2	78	—	—	2–78
7	Quartz and charcoal	9 5/8	77	17	60	—	17–60	—
	Average yield—all plots	9 2/3	—	—	—	—	—	—
8	Coarse gravel	9 1/2	227	28	199	12–76	10–61	6–62
9	Cinders	8 7/8	71	35	36	—	35–36	—
10	Charcoal	8 5/6	212	44	168	13–55	21–50	10–63
11	Low NO_3 (sand)	8 3/4	70	7	63	—	7–63	—
12	Coke	7 1/3	176	36	140	7–56	12–52	17–32
13	Low K (sand)	6 7/8	55	1	54	—	—	1–54
14	Soil	6 5/8	159	38	121	7–55	11–33	20–33
	Total 240 plants	9 2/3	2325	402	1923			

*First figure = splits.
SE = 7.96.
SEx = 4.6.
SE (difference) = 6.5–1 per cent point.
SE (difference between a replicated and an unreplicated plot) = 9.2–1 per cent point.

In estimating the significance of differences in these yields, a larger standard error of course must be used in comparing a yield in the replicated part of the experiment with one of the unreplicated plots than the ordinary standard error of a difference commonly used for comparing yields between replicates. Another consideration is the homogeneity of replicates.

Replication was systematic, that is, soil was used in plots No. 1, 11, and 21; vermiculite 2, 12, and 22, and so on. A generalized error was calculated for 21 plots (Table II) using only those seven treatments which were replicated three times. The total cut of flowers was used, as in practically every case "splits" were No. 1 grade had they not been split.

TABLE II—SEVEN REPLICATED TREATMENTS

Substrate*	Series 1	Series 2	Series 3	Total
Vermiculite	96	98	78	272
Fine Gravel	101	100	71	272
Sand	86	80	78	244
Coarse Gravel	88	71	68	227
Charcoal	68	71	73	212
Coke	63	64	49	176
Soil	62	44	53	159
Total 168 plants	564	528	470	1562

*All solutions WP.

While the "F" value for treatments in this calculation shows high significance at the 1 per cent point and the "F" value for replicates does not; still the "F" value for replicates does show a significance to the 5 per cent point. Since, then, odds are 20 to 1 against homogeneity between replicates, one should first note the position on the bench of a high yielding plot before putting any trust even in a yield that shows significance when treated with the high standard error above mentioned. The high yield in this experiment is such a one (high N and K in sand). It shows significance to the 1 per cent point when compared to the replicated treatment in the same substrate but with the check solution. The highest yielding plot, however, was in the section of bench on which the mean yield of all treatments was also highest and thus its validity as a high yield is questionable.

Series 1 cut the highest total number of flowers and series 3 the lowest. The validity of the (unreplicated) high N and K yield is questionable because it occurred in series 1, the series of highest total cut. The yield on quartz and bentonite barely shows significance when the high SE is applied, but this single plot was in low-yielding series 3 where the validity of the significance is not questionable.

Of the four yields from single plots which were higher than the highest replicated plots one other was significant (to the 5 per cent point) and this one (quartz and bentonite) was in the part of the bench where the mean yield of all treatments was lowest (series 3).

One season's results at best are not conclusive but tendencies are shown and taken with appearance and performance of plants through the year do indicate changes in the solution which may improve it materially.

Where nitrate and potash or nitrate alone were increased, the yield was better than that from the check solution. In both cases phosphate was lower in proportion to nitrate and potash than it was in the check solution. Thus it appears that the check solution has more phosphate than is necessary but is improved by the addition of nitrate. However, where the amounts of nitrate and potash were halved and the phosphate doubled, the yield was good. It is possible in this case that the solution was improved by the additional calcium of the monocalcium phosphate since calcium sulphate was the only other source of calcium in all plots except "quartz and bentonite". So much agitation is necessary to dissolve calcium sulphate that it was left in lumps when the other salts were dissolved. One hundred parts per million of calcium as calcium sulphate were used, though probably less than ten parts per million were in solution at any one time. The phosphate salt supplied forty parts per million of calcium in the check solution, so that doubling the phosphate practically doubled the calcium.

TABLE III—PARTS PER MILLION IN "BEST" SOLUTIONS COMPARED TO CHECK SOLUTIONS

Solutions	NO_3	(PO_4)	K
WP (check solution)	500	200	315
High nitrate and potash	1,000	100	630
WP and nitrate	1,000	200	315
Low nitrate and potash	250	400	157

The total concentration of solutions was of course varied by altering proportions of these three elements as above.

The progress report (1) describes the frequency of changing solutions, the leaching, and the manner of increasing concentration of solution in summer followed by a decrease in fall. These fluctuations may have been responsible for the considerable number of split calyces, but the number of flowers in any one treatment is too small to warrant an estimate of the effect of the solution on splitting. "Low nitrate", "low phosphate", and "low potash" are noticeably low in percentage of "splits" but the yield is also poor. The possibility that intensification of the pink markings in flowers of this white variety might be an indication of unbalance in the solution was also suggested in the progress report. Observations through the balance of the crop year failed to show any coordination of this symptom with certain solutions.

As previously described, fresh solution was given each plot every 2 weeks. Testing after it had been in use a week showed that nitrate fluctuated most widely when the crop was young (April and May). Phosphate was quite variable throughout the year, but fluctuated most from November to January. Potash fluctuated most from September to December but was quite constant thereafter. Some of this fluctuation was doubtless caused by the practice of leaching the substrates each time the solution was replaced — a practice apparently unnecessary, since one of the highest yielding plots was unleached throughout the year. Probably less frequent replacing of the solution would have given equally as good results too, although no actual proof is offered by this experiment. In most cases only one salt need have been added to bring it up again to "full" test.

It is concluded from this work that under the conditions of this experiment gravel and vermiculite are best of the substrates tested; that double the nitrate and potash and one-half the phosphate is superior to the check solution; and that replacing the solution every two weeks is unnecessary.

Acknowledgment is due Andrew G. Clark, Associate in Mathematics, Colorado State College, for very material aid in statistical analysis, and to the Experiment Station editorial committee for help in organization and clarification of content.

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Influence of Type of Cut on Rooting of Cuttings of Certain Greenhouse Plants[1]

By L. E. Longley, *University of Minnesota, St. Paul, Minn.*

RIGHT-ANGLED cuts are generally recommended by writers on plant propagation, but no experimental evidence is cited to prove the value of this type of cut. For instance, Adriance and Brison (1) recommend the right-angled cut although they say that in actual practice little attention is paid to the slope of the cut in species that root freely. In view of this the Division of Horticulture conducted an experiment in rooting of cuttings of a number of greenhouse plants.

Two types of cuts were used: (a) cuts at right angles to the stem, and (b) cuts made in a slanting direction with an agle of 35 degrees to 45 degrees at the basal tip. These cuttings were inserted in a greenhouse propagating bench and given ordinary care. Counts were made as to the number of cuttings finally rooting.

The results presented in Table I indicate that for the most part not much difference in percentage of rooting was obtained between the two types of cuts. A possible differential response was obtained from two species. *Coleus blumei* Benth. seemed better with the right angled cut and *Heliotropium arborescens* Linn. with the slanting cut. Seemingly with most greenhouse species the slope of the cut at the base of cuttings is not very important.

TABLE I—Rooting of Cuttings of Greenhouse Plants (Right-Angled Cut Compared with Slanting Cut)

Plant Material	Right Angle Cut			Slanting Cut		
	Number	Number Rooted	Per Cent Rooted	Number	Number Rooted	Per Cent Rooted
Helichrysum petiolatum DC.	190	105	55	90	49	54
Iresine herbsti Hook. f.	105	99	94	60	60	100
Pelargonium hortorum	159	121	77	77	53	69
Pelargonium domesticum	40	24	60	40	16	40
Pelargonium radula L'Her.	40	15	38	40	22	54
Pelargonium graveolens L'Her.	30	24	80	30	25	83
Santolina chamaecyparissus Linn.	100	45	45	100	45	45
Solanum pseudocapsicum Linn.	75	63	84	75	61	81
Begonia argenteo-guttata Hort.	50	39	78	50	43	86
Ageratum houstonianum Mill	75	71	95	75	68	91
Vinca major variegata Hort.	50	21	42	50	27	54
Abutilon hybridum var. *savitsi* Hort.	69	55	80	30	26	87
Alternanthera versicolor Ruiz & Pav.	200	196	98	194	182	94
Salvia splendens Ker-Gaul	100	78	78	100	89	89
Heliotropium peruvanium Linn.	30	9	27	30	21	70
Coleus blumei Beath.	178	170	96	150	126	86

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[1] Paper No. 1965, Scientific Journal Series, Minnesota Agricultural Experiment Station.

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Factors in the Rooting of Cuttings and the Growth of Young Plants

By ALFRED M. S. PRIDHAM, *Cornell University, Ithaca, N. Y.*

IN PRELIMINARY experiments, plants of *Ligustrum ovalifolium* were subjected to a period of 6 weeks storage at 40 degrees F. The plants had been grown on in pots from cuttings and were illuminated for 10 hours each day during the storage treatment. The foliage was thin and light green in color at the conclusion of the storage period and leaf bud cuttings were found to root freely and top growth followed immediately after potting. Similar cuttings taken from field grown plants had thicker dark green leaves; those from field grown plants from which a ring of phloem tissue had been removed a month previously, were much thicker and deeper green in color. Leaf bud cuttings from both control and ringed stems rooted freely but subsequent top growth was sparse and in many instances the rooted cuttings remained dormant until spring or longer.

In the present series mature field grown plants were dug on May 14th after foliage was well formed. The plants were set in 5-gallon pails and divided into three groups. The first group was grown on in a lath house, the second was placed in a cold storage chamber at 40 degrees F, and the third in cold storage at 50 degrees F. Young 3-foot plants of *Rhododendron catawbiense* variety *Roseum Elegans* were dug, set in 10-inch pots and stored at 40 degrees F. All plants in cold storage were illuminated 10 hours each-day by two 100 watt bulbs at 3-foot distance. Cuttings were taken at the end of 6 and 12 weeks.

Etiolation of field grown plants was accomplished by enclosing the upper portion of the shoot in a black manila envelop 10 inches in length. Rhododendron plants were also etiolated by covering them with opaque black cloth supported on a wooden frame. Treatment was continued for 7 day interval.

Cuttings from the above and from untreated plants were divided into groups of 25 and treated with Hormodin powder or were left for a period of 24 hours in aqueous solutions of alpha-naphthalenacetic acid, or sucrose, dextrose, levulose, maltose, potassium nitrate, ammonium chloride, ammonium nitrate, sodium nitrate, or a mixture of one of these with alpha-naphthalenacetic acid.

A mixture of equal parts by volume of quartz sand and German peat moss was used as a rooting medium. Frames shaded with cheesecloth and located in a propagating house were employed except for one group of Rhododendrons which was placed in coarse quartz sand in a chamber under a fine spray of water. The cuttings were examined periodically and removed when roots were evident. Rooted cuttings were potted and placed in a moist greenhouse.

Cold storage again resulted in thin, soft, light green foliage. Transplanting resulted in somewhat reduced growth and in relatively thick dark green foliage. Etiolation for a period of a week did not modify the foliage though slight wilting was evident and brown neurotic areas developed in a few leaves. Except where the opaque black cloth was

TABLE I—ROOTING AND GROWTH OF STEM CUTTINGS OF *Ligustrum ovalifolium* TAKEN FROM FIELD GROWN, FROM TRANSPLANTED AND FROM TRANSPLANTED AND COLD-STORAGED STOCK PLANTS

	Cuttings Taken Jul 25				Cuttings Taken Sep 2		
	Field Grown Active Growth	Transplant Active Growth	Transplant 40 Degrees F May 14	Transplant 50 Degrees F May 14	Field Grown Mature Growth	Transplant Mature Growth	Transplant 40 Degrees F May 14
			Untreated				
a*..........	100	50	53	60	40	30	38
b...........	70	91	100	96	7	—	60
c...........	2.0	1.5	2.2	1.7	—	—	—
			Hormodin 3				
a...........	100	100	100	90	36	84	84
b...........	68	91	100	100	00	00	100
c...........	2.0	1.3	2.4	1.8	—	—	—
			a-Naphthalenacetic acid 200 Parts Per Million				
a...........	100	100	100	95	76	72	100
b...........	75	92	100	100	00	00	100
c.	1.3	1.9	2.4	2.4	—	—	—

a = Per cent cuttings rooted after 30 days.
b = Per cent young plants in active growth after 60 days.
c = Mean number shoots per plant.

used, mortality in cuttings of etiolated stock plants was higher than in those from non-etiolated stock plants.

The preliminary experiments in the moist chamber supplied with a fine spray of water indicated retarded rooting in the untreated cuttings, earlier and more abundant in those from cold storage and better in those treated with Hormodin powder. In this chamber Hormodin treated cuttings averaged 80 per cent rooting while Hormodin treated cuttings in regular frames had a mortality of 80 per cent. Potted cuttings from the moist chamber suffered only slightly higher mortality than those from the regular frames but top growth was retarded.

The importance of the condition of the stock plant is evident from the data given in Tables I to IV. In root production this is as important

TABLE II—ROOTING AND GROWTH OF LEAF BUD CUTTINGS OF *Ligustrum ovalifolium* TAKEN FROM FIELD GROWN, FROM ETIOLATED AND FROM TRANSPLANTED COLD-STORAGED PLANTS JULY 25

	Field Grown	Etiolated	Transplanted 40 Degrees F May 14
	Untreated		
a..................................	36	24	100
b..................................	25	43	83
	Hormodin 3		
a..................................	76	65	100
b..................................	50	85	30
	a-Naphthalenacetic acid 200 Parts Per Million		
a..................................	95	89	—
b..................................	17	50	—

a = Per cent cuttings rooted after 30 days.
b = Per cent young plants in active growth after 60 days.
c = Mean number shoots per plant.

TABLE III—ROOTING OF STEM CUTTINGS OF *Ligustrum ovalifolium* AFTER 30 DAYS TAKEN FROM FIELD GROWN, TRANSPLANTED, AND TRANSPLANTED AND COLD-STORAGED (40 DEGREES F) STOCK PLANTS ON SEPTEMBER 2

Treatment of Cuttings	Stock Field Grown		Stock Transplanted		Stock Transplanted 40 Degrees F	
	Cuttings Check	Treated a.N.A.†	Cuttings Check	Treated a.N.A.†	Cuttings Check	Treated a.N.A.†
Untreated	40*	76	30	72	38*	100*
Sucrose .02m	28	96	44	76	52*	100*
Dextrose .02m	72	84	72	92	80*	100*
Levulose .02m	44	56*	40	72	68*	100*
Maltose .02m	36*	80*	56	88	56*	100*
Potassium nitrate 40 ppm	44	92*	—	—	44*	96*
Ammonium chloride 40 ppm	44	88*	—	—	28*	100*
Ammonium nitrate 40 ppm	28*	92	—	—	52*	100*
Sodium nitrate 40 ppm	48	92*	—	—	48*	96*

*Indicates top growth.
†Alpha-napthalenacetic acid 200 parts per million.

as the use of growth substances and its influence on top growth is more marked. Age or maturity of the wood has long been recognized as important. Transplanting of stock plants prior to taking the cuttings is of interest chiefly in stimulation of top growth. Root pruning might give similar results. Etiolation also stimulated top growth. Cold storage of transplanted stock was the most effective treatment aside from maturity of the stock plant. A temperature of 40 degrees F was more

TABLE IV—ROOTING OF LEAF BUD CUTTINGS OF *Rhododendron catawbiense* VARIETY *Roseum Elegans* AFTER 100 DAYS (STOCK PLANTS FIELD GROWN, TRANSPLANTED AND HELD IN COLD STORAGE JUNE 15, ETIOLATED 7 DAYS)

Treatment of Leaf Bud Cuttings	Cuttings Taken Jul 25				Cuttings Taken Sep 3		
	Field Grown Active Growth	Transplant 40 Degrees F Jun 15	Etiolated 7 Days		Field Grown Mature Growth	Transplant 40 Degrees F Jun 15	Etiolated Shoot Jul 18
			Plant	Shoot			
Untreated	73	84	84	61	16	80	32
Hormodin 1	64	83	80	68	24	—	4
a-Naphthalenacetic acid 100 ppm	71	73	56	38	28	96	12

TABLE V—ROOTING OF LEAF BUD CUTTINGS OF *Rhododendron catawbiense* VARIETY *Roseum Elegans* (CUTTINGS MADE SEPTEMBER 3 AND EXAMINED AFTER 100 DAYS) (RESULTS GIVEN AS PER CENT SAMPLE ROOTING)

Treatment of Cuttings	Additional Treatment of Cuttings	
	None	a.N.A.*
Untreated	16	24
Sucrose .02m	28	28
Dextrose .02m	16	24
Levulose .02m	20	4
Maltose .02m	00	4
Potassium nitrate 40 ppm	12	0

*Alpha Napthalenacetic Acid 100 Parts Per Million.

effective than one of 50 degrees and the period in cold storage need not exceed 6 weeks. Rooting took place in a shorter time and there were fewer roots and less callus formation. Bud break and top growth were early and abundant. Stimulation of bud break has been previously demonstrated in the storage of gladiolus corms (2). Cold storage of cuttings was not practical or effective.

The response to growth substances included greater callus formation, earlier and heavier root production. Sucrose stimulated root production in minor degree, as previously reported by others (1). Dextrose was effective but levulose and maltose were not. When sugars were used in combination with growth substances, callus formation and root production were stimulated slightly more than by either sugar or growth substances alone.

Various forms of nitrogen were ineffective in stimulating root production but when used in combination with growth substances had a minor stimulating effect on Ligustrum but not on Rhododendron cuttings.

Rooting of cuttings and subsequent growth of the young plant depends primarily upon the maturity and treatment of the stock plant. Response to treatments of cuttings with growth substances, sugars and nitrogenous compounds alone or in combination is of secondary magnitude and is much more variable.

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Color in Two Garden Chrysanthemum Crosses[1]

By L. E. LONGLEY, *University of Minnesota, St. Paul, Minn.*

FOR a number of years a breeding project with chrysanthemums has been in progress at the University of Minnesota in the horticultural division. Lately the emphasis has been on obtaining early blooming garden chrysanthemums.

Mulford (1) reports a very great degree of heterozygosity of the garden chrysanthemum strains with which he was working. Most crosses at Minnesota have given a very wide range of color.

This paper reports the observations on flower color obtained in two crosses: 1, Sunkist x 38A–3–36; and 2, Sunkist x 38A–97–24.

Sunkist has a bronzed orange-buff colored flower which is in the yellow-orange[2] color series. Selection 38A–3–36, obtained from a second generation progeny of Barnegat, has a Brazil-red colored flower in the orange-red color series. Selection 38A–97–24 obtained from a second generation progeny of United States Department of Agriculture No. 518 has a bright mallow purple flower in the violet-red color series.

Table I gives the record in regard to color of the seedlings of these two crosses. Color records were taken according to Ridgway's color chart, and the colors are grouped according to the proportion of yellow, orange, red, and violet they contain.

TABLE I—SEGREGATION OF FLOWER COLOR OBTAINED IN CHRYSANTHEMUMS WHEN YELLOW-ORANGE SUNKIST WAS CROSSED WITH ORANGE-RED (38A–3–36) AND VIOLET-RED (38A–97–24)

Yellow-Orange (Sunkist) Crossed With	Number of Segregates in Indicated Color Classes											
	W*	Y	OYY	OY	OYO	O	ORO	RO	R	VRR	VR	Total
Cross No. 1 Orange-red (38A–3–36)	0	0	42	11	1	85	58	11	7	0	0	215
Cross No. 2 Violet-red (38A–97–24)	4	4	5	4	3	7	14	2	12	47	86	188

*W = *White*
Y = *Yellow*
OYY = *Orange-yellow-yellow* (empire yellow, lemon chrome, pinard yellow, apricot yellow).
OY = *Orange-yellow and yellow-orange* (cadmium yellow, capucine yellow, Mars yellow).
OYO = *Orange-yellow-orange* (orange yellow, xanthine orange, cadmium orange).
O = *Orange* (orange-rufous, orange chrome, salmon orange, apricot buff, apricot orange, cinnamon, Sanford's brown).
ORO = *Orange-red-orange* and *orange-orange-red* (Mars orange, Brazil red, dragon's blood red, Morocco red, pinkish vinaceous, coral red, strawberry pink, hydrangea pink).
RO = *Red-orange* (vinaceous rufous, nopal red, English red).
R = *Red* (acajou red, carmine, oxblood).
VRR = *Violet-red-red* and *red-violet-red* (rose pink, mallow pink, amaranth pink, Tyrian pink, spinel pink, rosolane pink, Persian lilac, daphne pink, thulite pink, Indian lake, Bordeaux, pomegranate purple, rosolane purple, Schoenfeld's purple, pansy purple, amaranth purple).
VR = Violet-red (rose purple, Liseran purple, mallow purple, mallow pink, magenta, aster purple, dahlia purple).

Paper No. 1975, Scientific Journal Series, Minnesota Agricultural Experiment Station.

[1] Completion of certain parts of this project was made possible by workers on Official Project No. 165–1–71–124, Minnesota Works Projects Administration. Sponsor: University of Minnesota.

[2] All colors mentioned in this paper are classified according to Ridgway's color chart.

In cross No. 1 no color appeared except in the yellow-orange-red series. This is the only cross observed that produced such a result. Usually every cross will give colors of all sorts from white and yellow through orange, red, and violet. In cross No. 2 the color range runs from white, then yellow and orange-yellow through orange-red and into red-violet where the majority of the progeny appear, although 27 per cent are in the yellow-orange-red series.

From these data it may be concluded that white is recessive to the other colors and orange and red-purple are dominant. Also the seedling 38A–97–24 contains one or more factors for purple that are absent in 38A–3–36 and Sunkist. This is indicated by the absence of any progeny with purple in the cross between these latter varieties.

Also the absence of pure white and yellow flowered segregates in cross No. 1 suggests that selection 38A–3–36 may be homozygous for orange colored flowers. Selection 38A–97–24 appears to be heterozygous for its recessive color factors.

The flower colors in these crosses were classified according to Ridgway's color chart on the utilitarian basis for purposes of selecting varieties for flower gardens. This type of classification is not very satisfactory for genetic analysis.

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Studies of the Effect of Environmental Factors and Cultural Practices on Bud Initiation, Bud Abscission and Bud Development of the Gardenia

By Eugene Baird and Alex Laurie, *Ohio State University, Columbus, Ohio*

IN ORDER to determine the effect on gardenias of environmental factors an entire greenhouse was devoted to a series of tests. It was divided into two sections so that a high humidity could be maintained in one and a normal humidity in the other. A relative humidity of approximately 75 per cent was maintained in the high humidity section. The relative humidity in the dry section was normal to Columbus, Ohio, and varied from 50 per cent to 60 per cent, depending upon the outdoor conditions.

Since observations disclosed that gardenia buds set during the shorter days of the year, a study was undertaken to determine the reaction of the plant to photoperiodic response. By this reaction to photoperiodism it was hoped to get a marked set of buds for December production. Six-inch pots of *Gardenia veitchii* propagated February 15, 1940, from cuttings were used in this study. Ten plants per plot in each humidity section were shaded at three different intervals beginning July 1, July 15, and August 1. The plants were completely covered each night with black cloth from 5:00 p.m. until 8:00 a.m. from the time the shading was started until September 18, 1940. The house in which the plants were located was cooled from September 15 until October 10 at a night temperature of 58 degrees which is the normal cooling period thought necessary to set buds.

TABLE I—NUMBER OF BUDS SET PER PLANT TO DECEMBER 28, 1940

Treatment	High Humidity	Normal Humidity
Check	14.7	12.1
Shaded July 1 to September 18	17.8	26.4
Shaded July 15 to September 18	22.0	26.2
Shaded August 1 to September 18	21.4	21.6

About 1 month after the shading was stopped bud initiation took place on all of the new shoots of the shaded plants. Check plants failed to show this bud initiation. Production of the check plants occurred intermittently until December 1 and from then on decreased significantly until spring. The plants that were shaded produced no flowers until December 15, and all the production recorded occurred over a 3-week period beginning approximately at this time. The buds on the shaded plants reached a stage of full development but because of insufficient light remained at a standstill. To remedy this, supplementary light with 150-watt Mazda bulbs placed 1½ feet above the plants gave a minimum of 25 foot candles and was applied beginning December 7 from 5:00 p.m. until 10:00 p.m. Within 10 days the lighted plants flowered while the plants that were not lighted came into production 3 or 4 weeks later. Plants in the high humidity section developed their flowers faster and opened more rapidly than those in the normal humidity section.

TABLE II—Production to January 3, 1941

Treatment	Production Per Plant
High Humidity	
Check	1.7
Shaded July 1 to September 18	5.1
Shaded July 15 to September 18	3.1
Shaded August 1 to September 18	3.8
Normal Humidity	
Check	1.4
Shaded July 1 to September 18	4.0
Shaded July 15 to September 18	3.1
Shaded August 1 to September 18	3.4

Growth Substances and Bud Drop

The use of various growth substances to prevent the periodic fruit drop of apples suggested the possibility of its use to control the bud drop of gardenias.

Dilutions of 1, 5, and 10 parts per million were made from a 1 per cent stock solution of alpha naphthalene acetamide containing a spreader. These dilutions were freshly prepared for each weekly application and were applied from October 29 until March 27. Under our conditions and with these treatments the use of alpha naphthalene acetamide did not give significant control of bud drop.

TABLE III—Effect of Growth Substances on Bud Drop

Treatment	Buds/Plant	Per Cent Drop
High Humidity		
10 parts per million	37	13.5
5 parts per million	42.3	11
1 part per million	57.8	8
Check	61	7.6
Normal Humidity		
10 parts per million	53.8	14.5
5 parts per million	56.8	12.2
1 part per million	49.8	9.35
Check	58	11.7

Soil Temperatures

Since the effect of soil temperatures maintained by bottom heat upon chlorosis has given positive results, a study was made to determine the effect of bottom heat upon bud drop. Plants of *Gardenia grandiflora* var. Hadley propagated January 15, 1940, and planted May 29 in pecky cypress boxes 12 inches by 12 inches were used in each humidity section. Soil temperatures were maintained by the use of an electric cable running under each box. These cables maintained the desired soil temperature of 75 degrees by means of a soil thermostat. The soil temperature in the boxes where no bottom heat was applied was approximately 64 degrees.

TABLE IV—EFFECT OF SOIL TEMPERATURE ON BUD DROP

Treatment	Per Cent Drop
High Humidity	
Bottom Heat	3.8
Check	9.1
Normal Humidity	
Bottom Heat	9.1
Check	20.2

The plants supplied with bottom heat showed no chlorosis while the plants with the lower soil temperature developed some chlorosis during the dark winter months.

PEAT MIXTURES

With the present restriction on the source of imported sphagnum peats, experiments were set up to compare them with the domestic sedge peats. There was no significant difference in production and bud abscission between the plots of domestic peat and imported peat; however, during the summer and early fall before regular fertilizing practices were begun, the plants growing in domestic peat mixtures were larger and darker green than the plants in the imported peat mixtures. The sedge peat is known to have a higher nutritional value than the imported peat, and at the same time decomposes more rapidly than the sphagnum peat.

TABLE V—EFFECT OF ROOTING MEDIUM ON BUD DROP

Treatment	Buds/Plant	Per Cent Drop
High Humidity		
Domestic peat—1 part Soil—1 part	62.6	12.1
German peat—1 part Soil—1 part	43.5	11.5
Normal Humidity		
Domestic peat—1 part Soil—1 part	39	17
German peat—1 part Soil—1 part	59.4	13.1

GRAVEL CULTURE

In order to find differences between the production and bud abscission on plants grown in gravel culture and those in soil, a portion of a bench in each humidity section was devoted to gravel culture. The medium used for nutrient culture was leached coarse cinders. It was planted to *Gardenia grandiflora* var. McLellan "23", which had been propagated February 15, 1940, and benched May 29, 1940.

The nutrient solution used was the Ohio WP (1) which was changed to 2WP on December 8, 1940, and remained at this level until March 26, 1941, when it was reduced to WP again.

All testing was done according to Spurway. The nutrients were tested twice weekly and adjusted to the original levels. Additions of iron and manganese were made as needed. The results showed that gravel grown plants produced as well as soil grown but the quality of flowers in nutrient culture was superior to soil.

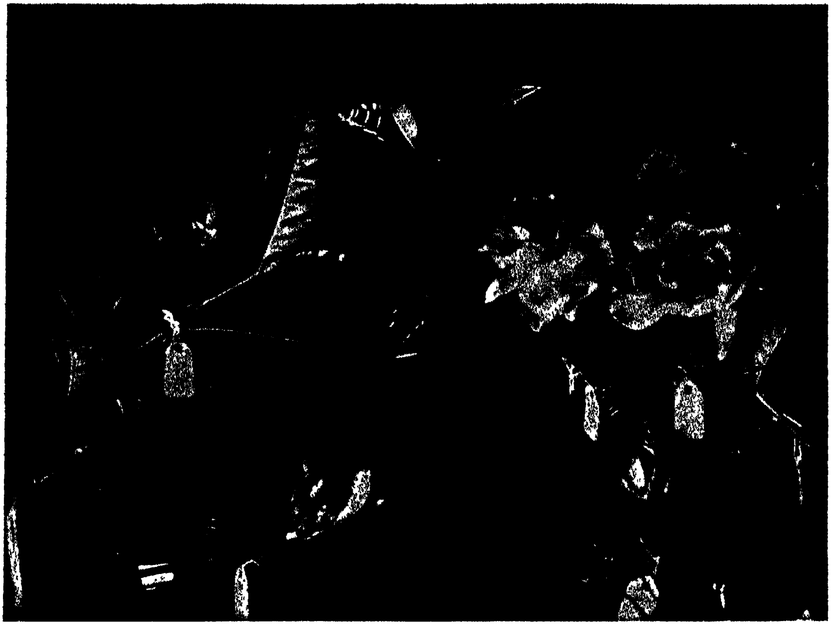

FIG. 1. Effect of shading followed by additional light on bud set and bud development of *Gardenia veitchi*. Plant on right — shaded July 1 to September 18, lighted beginning December 7. Plant on left — neither shaded nor lighted.

CONCLUSIONS

Short days are responsible at least in part for bud initiation in *Gardenia veitchi*. Additional light with a minimum intensity of 25 foot candles caused flowers to open more rapidly when applied in the late stages of bud development, December 1. The use of alpha naphthalene acetamide had no effect on the reduction of bud abscission in the gardenia. Soil temperature of 75 degrees was found to be conducive to less bud drop and reduction of chlorosis. No difference in production was observed in mixtures containing domestic sedge peat and those containing imported sphagnum peat. Gardenias grown in gravel culture produced as well as those grown in soil, but the quality in nutrient culture was better.

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Some Studies with Potted Plants

By CHARLES H. SHERWOOD and ALEX LAURIE, *Ohio Agricultural Experiment Station, Wooster, Ohio*

ABSTRACT

This material will be published in full in the *Ohio Experiment Station Bimonthly Bulletin.*

POINSETTIA (EUPHORBIA PULCHERRIMA)

THESE studies had to do with the commercial production of potted poinsettias as affected by soil aeration, watering, nitrate levels, temperatures and propagation.

In the studies with aeration the best plants resulted from the use of unscreened soil. The incorporation of 20 per cent of fine cinders to screened potting soil gave plants nearly as good. Heavy watering when the plants became dry was beneficial. Delayed watering at the time of panning was not satisfactory. Very little growth in either stem length or flower size occurred at low nitrate levels. High temperatures proved disadvantageous.

Growth promoting substances were very helpful in rooting. The speed and the number of roots per cutting was superior to that of those not treated. The best percentages of rooting resulted from cuttings 3¾ to 4½ inches long with an internodal basal cut made ½ inch below the node. Leaf bud and mallet cuttings were slow rooting but did afford a satisfactory and rapid means of increasing the variety.

EASTER LILIES (LILIUM LONGIFLORUM GIGANTEUM)

These studies included the effect of temperature, fertilizers and disinfection on Easter lilies.

The temperature treatments showed that as the period of time that the bulbs were left growing at 50 degrees F increased, the number of perfect flowers increased and the number of abortive buds decreased. The difference between 14 days at 50 degrees F and no time at 50 degrees F was one flower per plant and the period at 50 degrees F neither affected the flowering time nor the length of the stem. Increase of nitrates reduced bud count except when applied after bud set. Disinfecting the bulbs with colloidal sulfur was most satisfactory while disinfection with calcium hypochlorite was injurious at all concentrations.

SAINTPAULIAS (SAINTPAULIA IONANTHA)

Studies were made to determine the effect of light intensity and preconditioning on the formation of saintpaulia leaf spot.

Overhead watering with 75 degrees F tap water did not result in leaf spot at light intensities of 1000, 500 and 250 foot candles. At 1000 foot candles, sprinkling overhead with 60 degrees F tap water for even 2 days gave the symptoms of leaf spot. At the end of 2 to 3 weeks 60 degrees F tap water applied to plants under light intensities of 250 and 500 foot candles, respectively, gave similar symptoms. Foliage and flower growth of the 500 foot candle plots was the best under any condition.

Holding the plants, for 2 hours prior to sprinkling, at 50 degrees F, a light intensity of 25 to 50 foot candles, or in total darkness gave symptoms of the leaf spot when the sprinkling was done with tap or distilled water at 40 degrees F. The use of tap water at 65 or 90 degrees F under any of the preconditioning treatments did not result in injury.

It was concluded that overhead watering with water of the same temperature or warmer than the temperature of the plants is a safe procedure.

Propagation of the Ness Hybrid Oaks

By W. S. FLORY, JR. and F. R. BRISON, *Agricultural and Mechanical College of Texas, College Station, Tex.*

ABSTRACT

This material will be presented in full in a publication from the Texas Agricultural Experiment Station.

HYBRIDS were secured from the cross live oak (*Quercus virginiana*) x overcup oak (*Q. lyrata*) by the late Helge Ness in 1909 and 1910. The F_1 hybrids have the very desirable combination of good size, beautifully regular form, semi-evergreenness (at our latitude), and comparatively rapid growth rate; considerably exceeding either parent in this last respect. Eight or nine of these hybrids are growing on the Texas Agricultural and Mechanical College campus. They have not been previously propagated, and the present work has been carried out with the aim of increasing the hybrids for distribution.

A wide series of chemical and physical treatments of cuttings from the 30-year-old hybrids have given negative rooting results.

Insertion of T-buds at three different times of the year, and using 12 different forms of oaks for stocks, has also been followed by almost complete failure.

Propagation by grafting has met with considerable success to date. Bark, whip, and cleft grafts of hybrid scions on other oak stocks were made both in 1940 and 1941. Thirteen different stocks have been used. Whip and bark grafts on five specific stocks of the white oak group and on two hybrid stocks (between white oak species) have resulted in 175 (83.7 per cent) living grafts from 209 made in the 2 years. The successful stocks used are the following forms of oaks: live, overcup, burr (*Quercus macrocarpa*), post (*Q. stellata*), swamp white (*Q. bicolor*), F_2 (live x swamp white), and F_2 (live x overcup). Cleft grafts were less successful, probably due to the difficulty of getting good fits with this hard wood. Water (*Q. nigra*), black jack (*Q. marilandica*), Chinese (*Q. serrata*), and other red oak forms, have been relatively inefficient stocks regardless of the type of graft used. Sections for microscopic study of bark graft unions with several stocks substantiate impressions secured from field observations as to the relative goodness of union secured with the different stocks.

A Study of Perception and Appreciation in Landscape Design With Main Emphasis upon Proportions

By Robert S. Reich, *Louisiana State University, Baton Rouge, La.*

ALL of the arts as well as the sciences are built upon basic natural laws. All of these are closely interrelated (1). There exists an intimate relationship between the psychological process of perception and aesthetics, and thus between perception and landscape design, which utilizes horticulture as its main material of expression. To produce satisfactory arrangements the designer must have a comprehensive knowledge of this process of perception. While landscape designers have made some use of perceptual laws, further information is needed concerning their use in landscape design.

Landscape arrangements are usually produced because of the satisfaction they afford the designer. Undoubtedly many a designer produces his landscape arrangements because of a "feeling" that under the existing conditions these particular arrangements will afford the public a maximum of use and enjoyment. Unfortunately, however, his opinions usually are personal to such an extent that he never bothers to investigate the satisfaction these arrangements will afford the public. Although there are perceptual laws which can be used in producing desired effects, there are no laws to determine which effects are desirable. This is purely a question of judgment.

Thus, assuming that the designer understands the perceptual laws with which to produce desired effects, the important matter to determine is whether or not the general public is able to come to a definite agreement concerning the satisfaction afforded by various landscape arrangements.

The studies here described consisted of the development of a new technique to afford a more objective approach to basic landscape problems by producing various perceptual arrangements, determining the extent to which they are perceived, and recording the artistic appreciation for them. Two experiments were carried out to obtain judgments of people on the satisfaction afforded by various proportions in rectangular lawn panels. The observers also were asked to answer such questions as why they liked those proportions above others and (in the second experiment) which of the gardens in which the panels occurred they preferred and why.

To relate this work to a subject that had already received scientific experimentation the first problem selected (2) was the satisfaction afforded by various proportions in unadorned rectangular areas in landscape design. This allowed a comparison with the studies already made of abstract rectangular areas per se.

The main purpose of this second experiment was to ascertain the effect of any enclosure and of variations in the type of enclosure on the satisfaction afforded by various lawn panel proportions.

Since sufficient land and plants for such an experiment could not be secured, it was necessary to resort to scale models. Lawn panels of

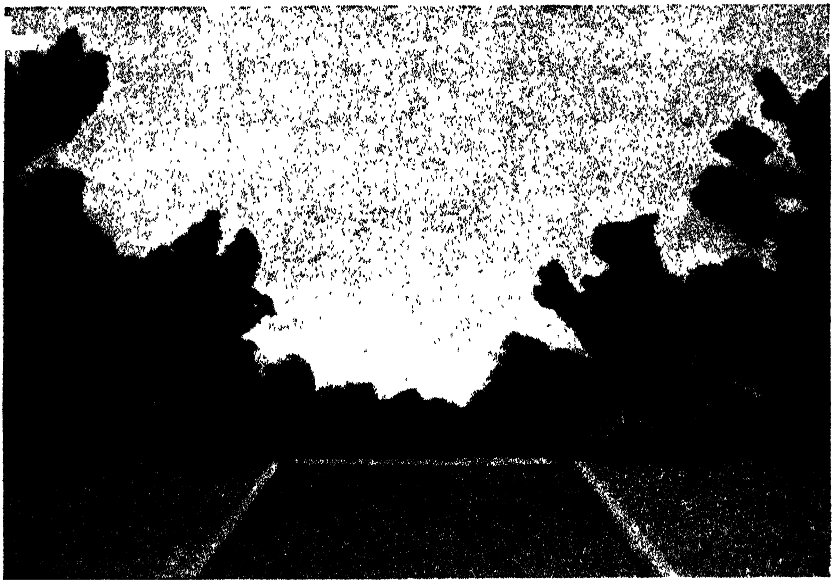

FIG. 1. Garden A.

several proportions, each of which appeared in several environments, would have involved a large number of models, taken too much space,

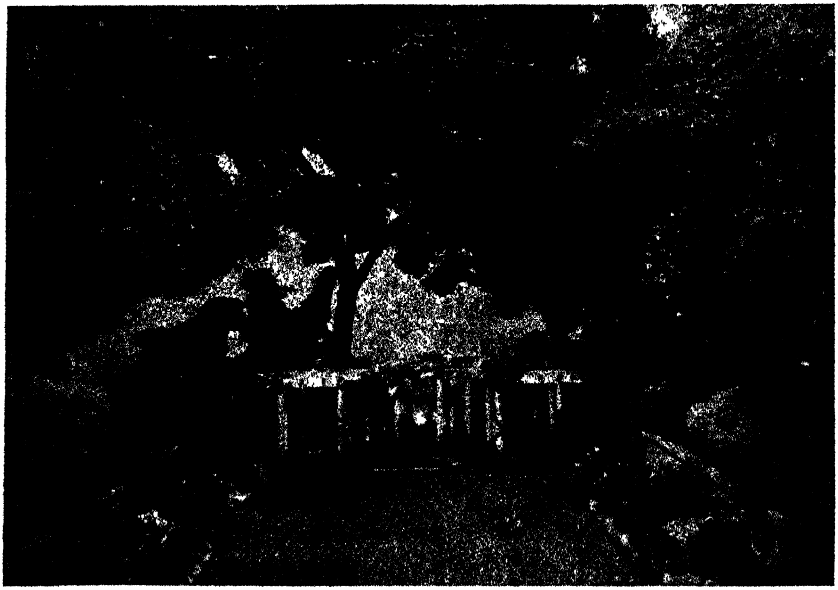

FIG. 2. Garden B.

and been discouraging to those taking tests. Three very different garden developments were finally selected. In the center of each was a lawn panel of fixed width and adjustable length. The width of the lawn panel in each of the three models was identical as also were the environment next to the eye of the observer, the sky, and the background.

The three models were constructed at the scale of 1-inch to 4 feet (see Figs. 1, 2, and 3).[1] Each was completely enclosed in a wooden case, 6 feet long, 3 feet wide, and 2 feet high. At one end there was an opening 8 inches wide and 23½ inches deep into which the observer placed his head. At the far end of this opening was a peephole. The observer with his head at the peephole could see nothing but the lighted garden beyond. Thus the garden appeared real, rather than as just a miniature.

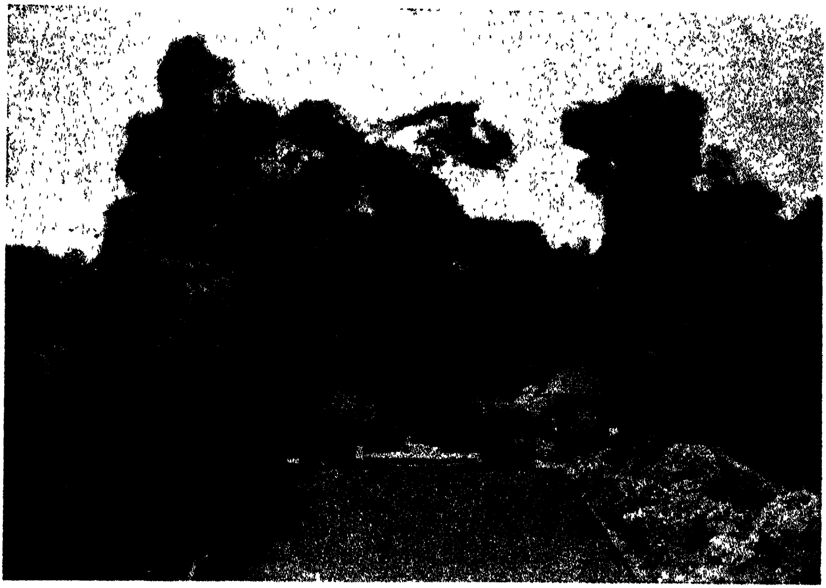

FIG. 3. Garden C.

Looking through the peephole the observer saw the far edge of a flagstone terrace and beyond it a sunken green rectangular lawn, surrounded on three sides by a low retaining wall. This much was identical in all three gardens. The differences in environment were produced by the plantings on the raised areas back of the retaining walls. By moving these raised areas backwards and forwards, the observer was able to vary the length of the sunken lawn. At its shortest length the panel proportions (width to length) were 1 : 1 and at its greatest length 1 : 4.

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[1] These photographs are far from perfect reproductions of the effects produced upon actually seeing the model gardens because: (a) the camera did not show as large an area as the eye was able to see; (b) the camera had to be set at a higher point than that from which the observers had viewed the gardens; and (c) the extremely important effect of color is lacking.

Garden A tended to repeat the openness of the field plots of the first experiment (2). However, some enclosing shrubs were necessary to hide the line of coincidence between the base and side of the box. This skyline, being kept low, gave the effect of space beyond. Except for these distant border plantings, the garden effect was of openness and extreme simplicity. The whole area between the retaining wall and distant border was suggestive of low wild field flowers and meadow.

Garden B was completely enclosed on both sides by large trees. A view of the distant sky, however, was seen under the lower branches of a big tree at the rear of the garden. The view, or axis, from the living room window (the peephole) was terminated by a pool, back of which was a curved pergola giving shadows of indefinite depth. On the wall back of the pergola was an additional axial emphasis, a delicate blue and white plaque, which could be seen through the columns. The garden was geometrically balanced, the treatment being identical on either side of the axis. The flower bed on either side was in reds and oranges. The garden was definitely formal, spectacular in effect, with the length accentuated.

Garden C was abruptly stopped at the far end by a heavy mass of trees and shrubs, but openings on the sides permitted views of indefinite distance, thus accenting the width effect. On the right the view extended over a bed of flowers and a wall to distant trees, shrubs, and sky. On the left the view extended under the allee of trees, through shadows of indefinite depth to the wall beyond and the shrubs beyond that. The axis was terminated by a pool, on the rear coping of which was a low reclining statue. Immediately back of this was a solid barrier of foliage. Tucked off in the far right corner was a tea house which, with a bed of blue and yellow flowers, balanced the allee of trees on the left of the panel.

The models were exhibited and judged at the Philadelphia meetings of the American Association for the Advancement of Science, at Cornell University, at the New England Spring Flower Show at Boston, and at the Buffalo Garden Center Show. A total of 3,238 ballots was cast for each of the three gardens.

Each observer, seated on a swivel stool, moved up to the peephole. As his eyes approached the peephole of the first garden, he was told that he was sitting in a living room looking through the picture window into the garden. After moving the garden back and forth as much as he desired, he left it at the point where the proportions of the sunken green lawn in the center appeared most pleasing to him. When he had completed this part of the project he was asked to indicate which of the three was most pleasing to him and which least, and to give the reasons for his decisions.

The data on the pleasingness of proportions were machine sorted according to the following 11 groups by the aid of Hollerith cards:

1. The 3,238 observers taken collectively.
2. The five places at which the gardens were exhibited.
3. Age of observers.

4. Sex of observers.
5. The observers' first choice among the three gardens.
6. The observers' last choice among the three gardens.
7. Whether or not the observer had a garden.
8. Whether or not the observer was a garden club member.
9. Whether or not the observer had studied landscape design in school or college.
10. Whether or not the observer read landscape literature.
11. Nineteen vocational groups.

Except in the age group, there was no pronounced variation in any of these groups from the choice of the entire group of 3,238 observers taken collectively. Youth apparently did not care for as much space. The younger the observers the shorter the proportions they preferred.

To simplify the analysis of the study of proportions the various panel lengths were divided into seven groups as follows:

1 : 1 to 1 : 1¼ referred to as the 1 : 1 range group
1 : 1¼ to 1 : 1¾ referred to as the 1 : 1½ range group
1 : 1¾ to 1 : 2¼ referred to as the 1 : 2 range group
1 : 2¼ to 1 : 2¾ referred to as the 1 : 2½ range group
1 : 2¾ to 1 : 3¼ referred to as the 1 : 3 range group
1 : 3¼ to 1 : 3¾ referred to as the 1 : 3½ range group
1 : 3¾ to 1 : 4 referred to as the 1 : 4 range group

Since the 1 : 1 and 1 : 4 groups include one-half as long a range of panel lengths as the other five groups, results for these two groups cannot be satisfactorially compared with those for the other five groups. However, if the 1 : 4 range had extended to 1 : 4¼ and there had been one or more ranges above that, many of the votes which did accumulate at the longer end of the 1 : 4 range probably would have fallen in ranges above the 1 : 4; the same can be said concerning the much smaller accumulation of votes at the shorter end of the 1 : 1 range.

Table I shows the most enlightening data used as a basis for the following summary of conclusions concerning the satisfaction afforded by the proportions of adorned rectangular lawn panels, under the conditions of this experiment.

1. Any enclosure increases the most pleasing width-length ratio from about 1 : 2 (for unadorned panels) to about 1 : 3.

2. The type of enclosure has no appreciable effect upon these proportions.

3. Both the long and short extremes, particularly the short ones, are decidedly less pleasing.

4. The golden section and root ratios (2) are in no way superior to any other ratios, and are less pleasing than many. In fact no one ratio is the best or better than immediately adjacent ratios.

While sunken lawn panels do not occur on every property, rectangular shapes of lawns, pools, terraces, and other developments are very common. The above conclusions undoubtedly apply to all rectangular forms seen in perspective.

The results of the second part of this experiment, on the satisfaction afforded by the three gardens, indicate that B was the most pleasing, C second most pleasing, and A decidedly the least pleasing (see Table

TABLE I—ANALYSIS OF THE VOTING FOR THE MOST PLEASING PROPORTION FOR THE LAWN PANEL IN EACH OF THE THREE GARDENS

Group	No. of Observers	Garden	Choice of Proportions Based Upon Percentages							Percentage of Observers Selecting the Proportions in Each of the Seven Ranges						
			1:1	1:1½	1:2	1:2½	1:3	1:3½	1:4	1:1	1:1½	1:2	1:2½	1:3	1:3½	1:4
1. Grand total of all showings	3,238	A	7	6	4	2	1	3	5	1.4	7.4	14.5	20.2	26.2	18.3	12.1
		B	7	6	4	2	1	3	5	1.5	7.1	15.3	21.8	25.6	18.0	10.7
		C	7	6	4	2	1	3	5	1.4	6.4	16.3	22.9	23.6	17.6	11.8
2. Experts (artists and landscape designers)	235	A	7	6	4	1	3	2	5	1.3	6.8	14.9	24.3	20.0	20.9	11.9
		B	7	5	3–4	2	1	3–4	6	0.9	9.4	17.4	21.3	26.0	17.4	7.7
		C	7	6	3	2	1	4	5	0.4	6.8	17.9	22.1	25.5	17.0	10.2
3. Age Groups: 15 to 17	133	A	6–7	4	1	3	2	5	6–7	3.8	13.5	27.1	21.1	21.8	9.0	3.8
		B	7	4	1	2	3	5	6	1.5	18.0	23.3	21.1	19.5	12.8	3.8
		C	7	4	1	2	3	5	6	0.8	13.5	30.8	26.3	16.5	6.8	5.3
18 to 20	251	A	7	5	3	2	1	4	6	2.0	9.6	16.3	23.1	27.1	15.9	6.0
		B	7	5	1	3	2	4	6	0.4	12.7	23.9	19.5	20.7	16.7	6.0
		C	7	5	1	3	2	4	6	1.2	8.0	23.9	24.7	22.3	13.9	6.0
21 to 24	268	A	7	5	3	2	1	4	6	0.7	9.3	16.8	24.3	28.0	14.9	6.0
		B	7	5	3	1	2	4	6	1.9	10.1	15.7	25.4	23.1	15.3	8.6
		C	7	5	2	1	3	4	6	0.7	9.0	23.1	23.9	22.8	13.8	6.7
25 and over	2,183	A	7	6	5	2	1	3	4	1.1	6.2	13.3	19.1	26.2	20.4	13.7
		B	7	6	4	3	1	2	5	1.3	5,3	13.7	21.7	26.4	19.2	12.5
		C	7	6	5	3	1	2	4	1.3	5.2	13.6	22.1	24.8	19.2	13.7
4. Sex: Male	1,293	A	7	6	4	2	1	3	5	1.5	7.6	15.5	20.4	25.1	19.3	10.7
		B	7	6	4	2	1	3	5	1.6	7.6	16.0	21.9	24.4	17.9	10.7
		C	7	6	4	1	2	3	5	1.5	7.9	15.4	25.4	23.7	16.0	10.2
Female	1,853	A	7	6	4	2	1	3	5	1.3	7.0	13.8	20.0	27.3	17.7	13.0
		A	7	6	4	2	1	3	5	1.3	6.6	14.8	21.9	26.2	18.3	10.8
		C	7	6	4	2	1	3	5	1.2	5.6	17.2	20.9	23.8	18.3	13.0
5. First choice Garden A	625	A	7	6	5	3	1	2	4	0.6	5.4	10.7	17.0	28.5	21.1	16.6
		B	7	6	4	3	1	2	5	1.3	6.4	14.1	19.4	24.3	22.6	12.0
		C	7	6	4	2	1	3	5	1.1	5.9	15.4	23.0	23.4	19.2	12.0
Garden B	1,378	A	7	6	4	2	1	3	5	2.0	7.4	15.0	21.6	24.2	18.0	11.8
		B	7	6	4	2	1	3	5	1.5	5.8	14.4	22.4	27.1	17.8	11.0
		C	7	6	4	2	1	3	5	1.4	6.5	16.4	23.8	23.9	16.6	11.5

TABLE I—*Continued*

Garden C	1,083	A	7	6	4	2	1	3	5	1.0	8.3	15.8	20.5	27.7	16.7	10.0
		B	7	6	3	2	1	4	5	1.6	8.7	17.0	22.4	25.4	15.2	9.7
		C	7	6	4	2	1	3	5	1.5	6.9	16.8	21.9	23.8	17.3	11.8
6. Garden club member																
Yes	311	A	7	6	5	3	1	2	4	1.0	3.9	11.9	18.6	28.3	21.2	15.1
		B	7	6	4	2–3	1	2–3	5	1.6	3.2	12.5	22.2	26.4	22.2	11.9
		C	7	6	4	3	1	2	5	0.3	3.2	14.5	21.2	26.4	20.3	14.1
No	1,361	A	7	6	4	2	1	3	5	1.1	6.2	15.1	20.9	29.1	17.3	10.1
		B	7	6	4	2	1	3	5	0.8	6.3	15.4	24.7	26.0	17.6	9.1
		C	7	6	4	1	2	3	5	1.0	5.8	16.5	25.1	23.6	17.0	11.0
7. Study landscaping at school other than Cornell																
Yes	242	A	7	6	4	2	1	3	5	1.7	6.2	12.8	21.5	31.0	16.9	9.9
		B	7	6	4	2	1	3	5	0.8	7.4	15.3	23.1	26.0	19.0	8.3
		C	7	6	4	1	2	3	5	1 7	7.9	14.5	24.8	23.6	16.5	11.2
Never studied landscaping	919	A	7	6	4	2	1	3	5	1.1	5.9	15.1	20.7	28.0	18.0	11.2
		B	7	6	4	2	1	3	5	0.9	5.9	15.1	23.0	26.6	17.6	10.9
		C	7	6	4	1–2	1–2	3	5	0.8	5.7	16.5	23.9	17.4	17.4	11.8

TABLE II—SUMMARY OF THE PREFERENCES OF THE 2,864 OBSERVERS WHO RANKED THE THREE GARDENS ACCORDING TO THE SATISFACTION THEY AFFORDED

Garden	Choice of Gardens Based Upon Mean Scores	Mean Score Given by the 2,864 Observers*
A	Last choice	0.72 ±0.10
B	First choice	1.24 ±0.10
C	Second choice	1.04 ±0.10

*These mean scores were obtained by giving each observer's first choice a score of 2, and last choice a score of 0, and giving the other garden (obviously his second choice) a score of 1. Probable errors are given with the means.

II). Under the conditions of this experiment the following general conclusions can be drawn from the reasons given by the observers for and against the gardens:

1. The average person thinks of a garden as a place for the display of colorful flowers.
2. Interesting architectural details, while much less important in a garden than bright colors, also are desirable.
3. Garden designs that are not strictly formal are preferable to the formal ones.
4. Spaciousness and freedom are desirable attributes. Overplanted effects should be avoided.
5. Garden designs should not have too much variety and interest. They should tend to be simple.

From these experiments it may be concluded that the public is in agreement concerning the satisfaction afforded by some landscape arrangements. Undoubtedly, experiments similar to these should be carried out to ascertain the relative satisfaction afforded by many other landscape arrangements.

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Conserving Our Harvests

(Presidential Address)

By F. C. Bradford, *U. S. Department of Agriculture, Glenn Dale, Md.*

THREE and a half centuries ago Francis Bacon said: "I take all knowledge to be my sphere". Though competent scholars state that Bacon was far from having full knowledge of the science of his day, his aspiration was not ridiculous or even particularly remarkable in his time, and had he given to science half the time he devoted to statecraft he might well have mastered all the science that was then known. An Italian contemporary of Bacon, Giambattista della Porta, made studies which are still mentioned in histories of optics, included in his extensive Magia Naturalis a chapter on producing new plants — probably the first organized article on plant breeding — wrote a work on plant signatures and in modern literary histories he is discussed as the leader of the notable group of writers of Italian comedies in a period when Italian comedy was the most notable literary movement in the world. A century later the best known English writer on gardening, John Evelyn, by whom greenhouse heating was considerably advanced and gardening made respectable, was only a part-time horticulturist; he was also an authority on some of the fine arts and rather constantly engaged with public affairs. Most of the German pomologists of the early nineteenth century made their extensive varietal studies and wrote their monumental works in time spared from their labors as pastors or teachers. When our own agricultural colleges and experiment stations were organized, nearly two centuries after Evelyn, full time horticulturists were rare in their staffs; most of the pioneer teachers and investigators not only worked on the various phases of horticulture, but also served either as botanists, entomologists or pathologists and sometimes as foresters and superintendents of grounds. Many horticulturists now in active service have taught or investigated pomology, olericulture, greenhouse construction, floriculture, plant breeding and landscape gardening. They have in numerous cases seen one-man departments grow into sectionalized departments, with staffs of 20 to 30 men.

The two needs most conspicuous when this expansion began, research and extension, have received most attention, with results that are most gratifying. The successive volumes of Proceedings of this Society provide a graphic presentation of cumulative increase in horticultural research. If all vehicles of publication of horticultural investigation were considered, the equation representing the increase might approach that of accelerated motion. Increase in horticultural research is not confined to the United States. Many other nations have research stations doing work of a high order, most of them comparatively new. As an example, it may be noted that pollination studies on the Bartlett pear have been reported in Australia, Canada, South Africa, Switzerland, Germany, England, the Scandinavian countries, the United States and possibly other countries. There need be no concern about quantity.

The Proceedings of this Society also illustrate very well a great improvement in the quality of the work done; the increasingly frequent appearance of articles by horticulturists in the journals of the pure sciences furnishes additional evidence of the quality of the research done in horticultural departments and, conversely, physiologists and anatomists are increasingly utilizing horticultural material in their own research. It is true that improvement in quality is still needed, here and there, but the best promise of that improvement is the self-examining attitude of research workers, and their concern for the quality of their work. Some improvement in choice of problems, more concerted attack from various angles, are needed, but these concern direction of research primarily, rather than its excellence.

On the whole, then, our research work is sound and with proper support can be relied on to continue in that condition, so far as present signs are indicative.

The very productiveness of research and its advanced nature have, however, created a new problem, rapidly becoming acute, through the inadequacy of the existing mechanism to the task of digesting and assimilating research results, incorporating them into the existing body of information, with such modifications of this body as they may necessitate, to the end that the whole body of information is always complete and always ready for use. Thirty years or so ago, this problem was much less pressing. There is abundant evidence that the horticultural teaching of that period was far from utilizing all the information then in existence, largely because it was not in readily available form, and the horticultural teacher of those days had too many subjects to cover to permit him to develop any subject thoroughly by library search. In spite of this failure to utilize existing information already stored on library shelves, the horticultural investigator and teacher had no great difficulty in keeping abreast of current investigations on horticultural crops. The first comprehensive American experiments on orchard fertilization and orchard management were just approaching publication; spraying employed only three or four standard materials; the first serious studies on storage were still new. Most of the experiment station work was published in bulletins and these were so few that each one was studied and discussed by all horticultural investigators and teachers. The average investigator of that period worked on projects covering nearly the whole range of horticulture and could keep abreast of current literature on all of them without losing much sleep. A volume of the size of any of our Proceedings would contain all the horticultural research published in several years in the earlier period.

Thus little more than 30 years of horticultural research and teaching have developed a stage of specialization so advanced that in the institutions with the larger staffs each member, it has been said, continually knows more and more about less and less. Sheer abundance of information is increasingly circumscribing the field in which each man can keep thoroughly or even well informed. In many fields the investigator could spend so much of his time reading pertinent literature that he would have scant time for research of his own. It is doubtful whether any student of hormones could read all the papers on hormones that have been printed in the last 10 or even 5 years, and still do research. The student who would read all current literature on citrus fruits in the original papers would need command of at least English, French, German, Spanish, Portuguese, Italian, Russian, Dutch and Japanese. If the literature on limited fields taxes or exceeds the time and energy of the specialist in those particular fields, it is manifest that he must fail to keep well acquainted with related fields and his reference to them throughout his working life is in many cases based on what he learned in college.

Changes in the techniques of investigation have been even greater than those in quantity. Chemical methods, plant physiological techniques, virtually unknown in horticultural investigation 35 years ago, have become common. Statistical analysis was then new in the biological sciences and no horticultural research had been placed under its scrutiny. Genetics was a new term. Little was known about plant viruses. Each of these techniques is ever progressing, each has its own growing literature. Thus modernization of implementation requires that the investigator be constantly alert; this in itself is a considerable task. The increasing requirements of attention to methodology inevitably limit the time available for thoughtful study of literature of those phases of horticulture that do not occupy the investigator at the moment. Little by little each of us has been forced to neglect readings we should accomplish. No other course is open. That we may retain even approximately complete command of some subjects, we must leave others rather largely in status quo and before long our occasional dealings with them are made with incomplete knowledge.

Wisdom is not a new invention. If research is sound its value is not ephemeral. None the less the very machine that was created to produce facts is by its own exacting requirements and its productivity burying facts under other facts unless they have an immediate cash value. It would be very comforting could we believe that some vaguely defined buoyancy kept everything valuable afloat on the surface while the trivia were engulfed; unfortunately this is not the case. Discoveries of great value have been ignored because their importance seemed small at the moment of their enunciation. When Nicholas Longworth induced the son of a Cincinnati market gardener to reveal the secret of securing crops from pistillate strawberries, the use of pollenizers quickly became general and was not forgotten, because pistillate varieties were being grown commercially. This "secret" had, however, been published in England in 1815 and in France nearly 50 years earlier than that and had been forgotten because it had no important immediate application. These reports were not in obscure journals; one had been published in the Transactions of the Royal Society; the other in a standard book. Mere publication evidently is not enough to insure continued recognition.

We who are here present will collectively hear literally hundreds of papers at this session; these will be neatly printed and the collection will take its place on library shelves, alongside thirty-odd similar volumes. But this is not the end. Research will not die with the closing of this session. Another volume will be added next year and the next and so on. The students who come into the field in 1951 will be so busy reading the new volumes that few of them will ever get back along the shelf to the 1941 volumes unless specific reference sends them to it. Thus the study that cannot at once be tied to something useful can become buried in 1941 as in 1760. If this material is worth the time, effort and resources that have gone into its preparation and publication, it is worth the additional effort that will be necessary to keep it accessible.

This confusion, if not chaos, into which we are proceeding at a rapid rate is due to our failure to recognize our increase in wealth. We are still using the machinery and methods that were reasonably adequate 40 or 50 years ago, unconscious that we have outgrown them.

Specialization has beyond question been productive of good results, but doubt may well be raised as to whether, in its present form, it can continue to function smoothly when the influence now exerted by the older men with broad experience is no longer felt. Already there are disturbing signs. Sometimes recommendations are made to alleviate one difficulty, without due consideration of all the effects of these recommendations, simply because the other effects lie beyond the specialist's purview. When staffs are composed entirely of specialists the lack of integration is likely to become acute. On the other hand, wide areas, thousands of farmers, still take their immediate guidance from horticutlural staffs so small that one man may be their reliance in a wide diversity of subjects as, conceivably, rootstocks, winter injury, boron deficiency and fruit storage. A position with this responsibility needs a more capable man than is required for any single position in a large staff. Usually a man in this situation has the most meager library facilities and the greatest imperative demand on his time. It is not surprising, therefore, that in occasional cases a practical grower has quoted published research of which the investigator had not heard.

This condition has developed, obviously, through nobody's intent and many are still unaware of its existence. The investigator naturally does not advertise his failures to keep fully abreast of the times. The administrative official cannot know many fields as well as the specialists in those field know them and as long as their work is good he must assume that it could not be better. If he has suspicion that some phases are being neglected his usual remedy is to hire another investigator.

Responsibility for this situation rests basically even more on the colleges of agriculture than it does on the experiment stations. They have followed the pure sciences in exalting the investigator and ignoring the scholar. The whole structure of the requirement for the advanced degrees, particularly the doctorate, in agricultural subjects as in pure sciences reflects this with the greatest clarity. In the days when advanced degrees were first awarded, the literature of science was so comparatively limited that mastery of it was easily attained by the candidate and his thesis was required to demonstrate his ability to conduct independent research. Thus the early Doctors of Philosophy could legitimately claim to be scholars and investigators. For some time it has been apparent that doctorates are being awarded to men who do not know thoroughly the literature of even their own science beyond the field of their theses, but no official recognition has been made of the polite anachronism involved in welcoming Doctors of Philosophy into the fellowship of scholars. Despite the great change in lines of work followed by graduates of agricultural colleges, despite their influx into industries connected with agriculture, the graduate student who wishes a degree, whatever his purpose, must still demonstrate his ability to conduct independent research. A teacher in a Smith-Hughes agricultural high school who wishes to supplement the studies covered in his undergraduate curriculum may need advanced courses in many branches of agriculture, but if he wishes the Master's degree as a token of extra study beyond the baccalaureate degree he must abandon thought of advanced courses in various agricultural subjects, concentrate on one and demonstrate through a thesis that he can conduct investigation. When he has done this, he may secure an increase in the stipend he is paid for teaching. A youth contemplating a career in industries related to agriculture is likely to secure better preparation for this career by taking the Bachelor's degree in two institutions than he will by taking graduate work. Many respectable institutions are now conferring the Master's degree for advanced course work, but agricultural colleges rather uniformly seem to be content to pour all their material into the old moulds. Agricultural study was once hailed as an escape from the rigid requirements of the old classical curriculum; with age it seems to become rigid in its own way.

Every institution which awards the doctorate in literature and in history grants it for work which in the scientific field would be called discussion of the literature. There is no question of the value of this kind of work or of its repetition; the factual records of history may not change but their interpretation changes with every generation. Only in pure science and in agriculture is this type of study without formal recognition. Official agriculture, whose every effort is sincerely in the direction of making the world's knowledge available to the humblest farmer, expends great effort on research and on extension but assumes that systematization of information is an autocatalytic reaction.

Were the effects of this present traditional grooving confined to the misfortunes of the individual students who do not fit into it, they would be deplorable enough. Actually they reach much farther and affect us all. The standard requirement for the advanced degree exalts research work and inevitably establishes some unfortunate implications of relative values of different legs of the table. This notion is all too common. Naturally it leads to differences in preferment. Extension men have their methods of securing reward, often through "pressure groups", and administrative officials appear to secure a glow of mellow feeling from rewarding the work of the successful research man, who, presumably, exerts no pressure. When these groups are cared for if there is any balance, part of it is given to the teachers, unless the campus needs new sidewalks. Scholarship fares better in the humanities than it does in the sciences, or in agriculture.

Thus the cycle is maintained. The horticulturist soon becomes aware of the directions in which lies preferment and he "builds his fences out in the state" or he pushes his research—in any case he neglects his teaching in greater or lesser degree. The bright ambitious young man seeks ardently for full time research or goes into extension, and the passing of time finds considerable numbers of men doing teaching because they were complaisant and lacked aggressiveness, rather than through any special aptitude. Teaching done by the research man is all too frequently very minute, detailed and exact in the portion of the course that pertains to his particular field of research and very shabby in the other portions. Sometimes two-thirds of the student's time in the course is given to the teacher's research field and the remaining third to the rest of the subject. This is an easy way of discharging an unwelcome task.

Unfortunately a teachers' success cannot be measured accurately until the students he had in his middle age have themselves become middle-aged. Administrative officials have some real difficulty in this appraisal, for they cannot wisely rely very much on student opinion. They could, however, assure themselves that the candidate teacher is a scholar through the guarantee of his mastery of the literature of his subject that is implied in a degree awarded for scholarship, far better than by his standing as an investigator of a limited portion of the subject he teaches. Attainment of a degree awarded for scholarly mastery of a subject, without reference to research proficiency, should be the preferred standard for selection of teaching personnel. Were all agricultural students prospective investigators, the present arrangement would be satisfactory; they are not and it is not.

Scholarly systematization of knowledge and its publication could well form a part of the program of every institution. Publication of such works should not drain seriously the publication funds, for if proper standards are maintained, contributions of this sort will be far less numerous than the research papers. Publication of critical literature reviews would have several beneficial effects; it would make readily accessible in a few minutes information whose gathering and collation required months and years; it would grant recogntion to those who perform these labors and it would invite appraisal of the quality of their work, as do the papers written by investigators. Unwisely executed, this effort would be perilous for it could become misleading. High standards should be exacted and consultation with many specialists would be necessary; the work should be critical review and not unquestioning compilation.

The influence exerted by men whose chief responsibility and greatest distinction lay in providing complete, digested and evaluated information would be felt in many directions. It would constitute a strong force in a direction needed now more than ever, namely, coordination of research. It would relieve investigators of much of the labor of searching through great masses of reading to glean a small grist of pertinent matter, though it should not relieve them of responsibility for study of this modicum. More than one productive new line of investigation has been suggested only after assembly and review of all the available pertinent facts. With specialization becoming more advanced, men of this somewhat more general training could be of great value to administration of horticultural organizations.

Investigators are relying increasingly on abstract journals to bring their general information down to date. Therefore it is most humiliating to be forced to acknowledge that lack of support is making abstract journals increasingly inadequate. To secure reasonably complete coverage of horticultural literature, its student must resort to foreign abstract journals, admirably conducted, but still abstracted abroad and principally for use abroad. As a rule, abstracting done abroad is a paid service; in the United States it is almost entirely voluntary. This may have some influence on the results, but much more inhibitory on the usefulness of our abstract journals is the limit placed by lack of funds on the space that can be allotted to any subject. This situation could doubtless be remedied by proper presentation of the value of the service and of its present inadequate coverage. It is possible, too, that abstract journals could increase their usefulness and their revenues by adopting a format lending itself to printing and sale of reprint separates that could be distributed readily into various files.

Though improvement of our abstract journals is very important and should be pushed energetically, principally by better support, these journals cannot, however well conducted and however voluminous, be more than an adjunct in keeping our information continuously organized. Let anyone who doubts this statement drop all pertinent notes on any one subject into a file for 10 or even 5 years, and then try to comprehend the mass in time to answer a telephone call. Librarians' lists of titles give only a start in this direction, for titles are often misleading as to content. Sporadic literature reviews introducing reports of investigation are increasingly inadequate, for they properly ignore material not relevant to the investigation and they do not constitute a uniform progression covering a whole field. Whatever devices may be tried, there is no escaping the need of men trained in horticultural scholarship. These men should know the art of horticulture and know the supporting sciences; their linguistic attainments should be extensive; their geographic and historical knowledge should be adequate to permit evaluation of any piece of research in relation to its background; they should be proficient in finding, collating, organizing and presenting information. They should find their chief delight in doing work of this nature. They must be able to consult freely with appropriate specialists for critical evaluation of research reports. This is, to be sure, almost the identical set of specifications that should be used in developing a good teacher. It involves far more, however, than it did a few years ago in preparation, attainments and experience and it deviates rather considerably from the work reasonably expected of an investigator. That it is not often realized at present is due to our persistent effort to make teachers out of men trained to be investigators. Work of this sort needs, therefore, official recognition as a definite career, honored equally with cognate lines of effort, with a definite line of approach, a definite outlet for its products, definite allowance of time and resources for its pursuit and definite reward for excellence in attainment. The man thus trained and thus employed could well become more than a specialist engaged to cure the effects of specialization; he is the most likely of all to develop into the architect who builds structures from materials made by many men. Let us remember that Darwin accomplished as much or more by putting together scattered bits of information brought forth by others than he did by his own personal investigations.

MEMBERSHIP ROLL FOR 1941

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